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ISSN 1823-6782

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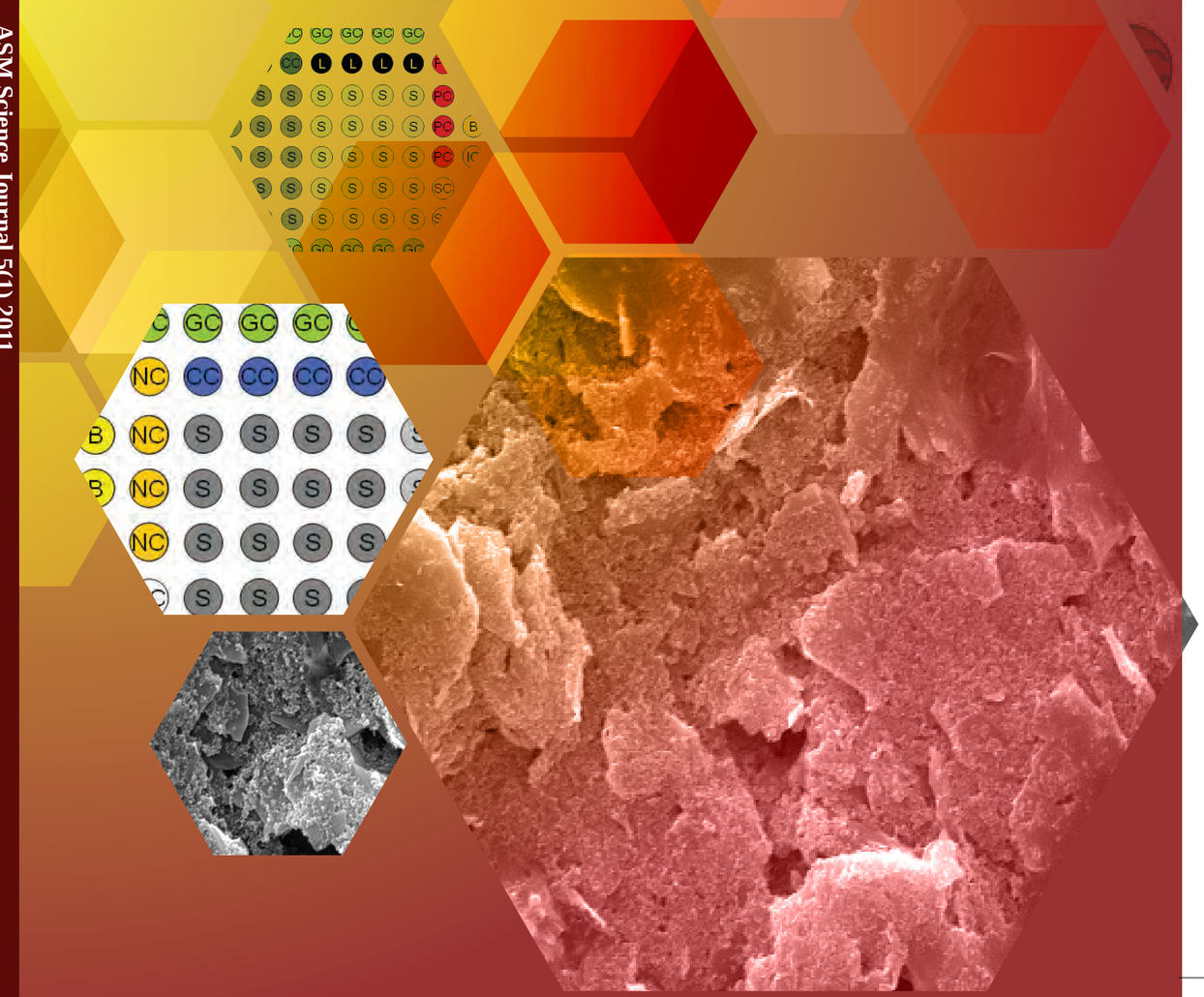
ASM Science Journal 5(1) 2011

ASM Science JOURNAL

In Pursuit of Excellence in Science

Vol. 5, No. 1, June 2011 • ISSN : 1823-6782



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Cover:

The semblance of mosaic pattern depicts (1) Figures 3 (ii) of pages 40 and 41— scanning electron micrographs of the carbon reactive surface of screen-printed carbon electrodes at room temperature (the largest hexagon and the adjacent smaller hexagon in grayscale), in the article entitled *Physical Characterization of the Screen-printed Carbon Electrode Surface Using Scanning Electron Micrograph* which describes how scientists from the Institute for Medical Research, Malaysia have developed and modified DNA biosensor techniques to provide a fast, simple and sensitive method for detection of human diseases, bacterial food contamination, forensic and environmental research; and (2) Figure 2 of page 50 which is a layout for standard cytotoxicity testing comprising various controls, in the article entitled *European Centre for Nanotoxicology: A Proactive Risk-assessment Nanotechnology Initiative* (the glaring white hexagon with round spots) — the article introduces the European Centre for Nanotoxicology (EURO-NanoTox), an Austrian hub for scientific knowledge in the field of nanotoxicology.

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Estimation of Double Shear Strength of Timber Connections Fastened with Glass Fibre Reinforced Polymer Dowel by National Design Specification

H. Rohana[1]*, I. Azmi[1] and A. Zakiah[1]

Current National Design Specification (NDS 2005) provides the guideline to design timber joints strengthened with steel fasteners. This study investigates the possibility of using NDS 2005 to estimate the load-carrying capacity of timber joints fastened with Glass Fibre Reinforced Polymer (GFRP) dowel. Double shear timber joint fastened with steel dowels were tested to validate the joints fastened with GFRP using 1.27 cm diameter dowels. Tests were also conducted to determine the dowel bearing strength of wood and dowel bending strength of GFRP and steel. The failure modes of all tests were observed and recorded. Results showed that NDS (2005) successfully estimated the failure mode and was capable of predicting the joint load-carrying capacity when fastened with a GFRP dowel and this was well validated by the load carrying capacity of a steel dowel.

Key words: European Yield Model; Kempas (*Koompassia malaccensis*); guideline; steel fasteners; load-carrying capacity; bearing; bending; tests; failure mode

The National Design Specification (NDS 2005) specifies the design of a timber joint using steel type fasteners such as nails, bolts, screws, staples and dowels. In NDS (2005), the model used for estimating the load-carrying capacity of joints strengthened with mechanical fasteners is the European Yield Model (EYM). This EYM model was developed from analysis of the lateral yield strength of a timber connection using single-dowel fasteners such as nails, bolts and dowels.

The load-carrying capacity of a joint is based on the bending yield of the fastener and the bearing strength of the wood. Wood joint behaviour is very much affected by its moisture content and also its strength. However, the load-carrying capacity of this joint is also affected by other parameters such as the diameter and yield strength of the fastener, and the thickness of the joint members. The EYM has been accepted as the model to estimate the load-carrying capacity of timber joints. This model is documented in two different standards/specification for timber joints namely the National Design Specification (NDS 2005), published in United States of America and Eurocode 5 (EC5 2008) published in United Kingdom. In deriving the equation of EYM, these two standards have used different approaches as in the determination of the design load capacities; there are differences between these two codes. The yield values from load-displacement curves in NDS were recorded from the 5% diameter offset values (Mclain 1993) while in EC5, the yield values were recorded at ultimate load capacities (Ehlbeck & Larsen 1993 and Smith *et al*. 2005) These yield points are as shown in Figure 1.

Since the timber joints can fail in different modes of failure, the double shear strength test has been accepted as a method to determine the yield modes of timber connection in both NDS and EC5. For the NDS, the failure modes are categorised as I_s, I_m, III_s and IV with respect to different equations of characteristic load-carrying capacity as shown in Table 1. The lowest value out of four equations is taken as the failure load of the connections.

EYM has been accepted globally as the engineering approach in joint design since it was developed by Johansen (1949). Investigations on the robustness of EYM in estimating the load-carrying capacity of timber joints was further explored by Larsen (1973). Later, the model had been modified by other researchers with different parameters so as to verify the performance of nailed joints (Aune & Patton-Mallory 1986) and bolted wood joints (Mc Lain & Thangjitham 1987; Soltis & Wilkinson 1987 and Jumaat *et al.* 2008) or both (Smart 2002; Smith *et al.* 2005). Estimating wood joints which has been strengthened using wood dowels were investigated by Sandberg *et al.* (2000) and Eckelman and Haviarova (2007). The application of EYM for mortise and tenon joints strengthened by wood dowels has been studied by Shanks (2005), Schmidt (2006) and Miller (2004). EYM has also being applied to simulate the response of degrading hysteretic joints (Heine 2001) and

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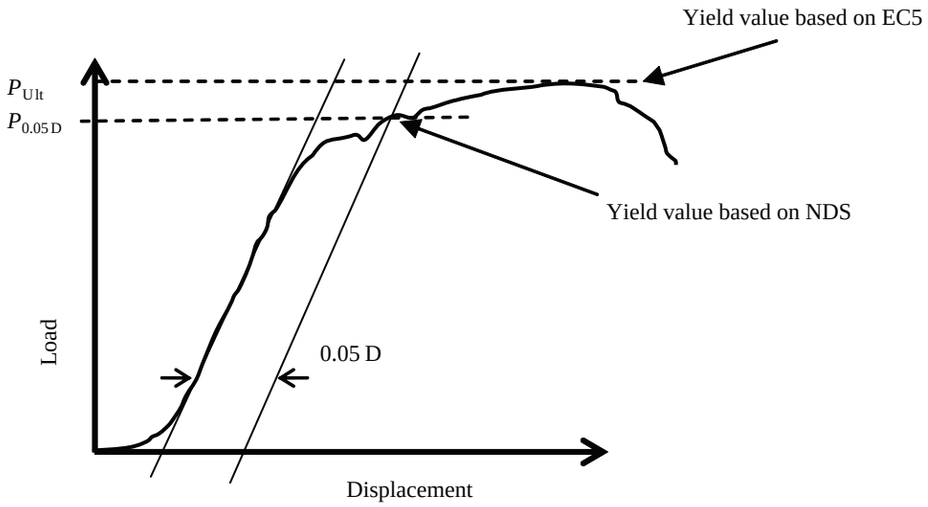
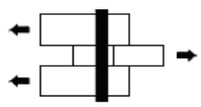
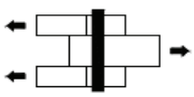
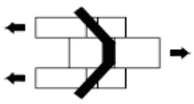
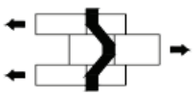


Figure 1. Determination of ultimate load, P_{Ult}, and 5% diameter offset load, $P_{0.05\,D}$ from a load-displacement curve.

Table 1. EYM formulas according to NDS 2005.

Failure mode	Characteristic load-carrying capacity (Z)	Equation no.	Descriptions
	$\frac{Dl_m F_{em}}{4K_\theta}$	I_m	Dowel bearing failure or crushing of the main member
	$\frac{2Dl_s F_{es}}{4K_\theta}$	I_s	Dowel bearing failure or crushing of the side members
	$\frac{2k_3 Dl_s F_{em}}{3.2(2+R_e)K_\theta}$	III_s	Two plastic hinges form with crushing of wood fibres in the side members
	$\frac{2D^2}{3.2K_\theta}\sqrt{\frac{2F_{em}F_{yb}}{3(1+R_e}}$	IV	Two plastic hinges at each shear plane

Where,

$$k_3 = -1 + \sqrt{\frac{2(1+R_e)}{R_e} + \frac{2F_{yb}(2+R_e)D^2}{3F_{em}l_s^{\,2}}} \quad (1)$$

$$R_e = \frac{F_{em}}{F_{es}} \quad (2)$$

and

$$K_\theta = 1 + \frac{\theta}{360} \quad (3)$$

where D is the bolt diameter; l_m is the dowel bearing length in main (centre) member, l_s is the dowel bearing length in one of the side members, F_{em} is the dowel bearing strength of main (centre) member, psi; F_{es} is the dowel bearing strength of side member, psi; F_{yb} is the bending yield strength of bolt, psi and θ is the maximum angle of load to grain ($0^o \leq \theta \leq 90^o$).

for cyclic loading group action factor (Thomas 2006) and on bolted connections in wood plastic composites (Balma 1999). Above all, EYM is suitable for some of the study materials and joints, significantly a few found it is rather difficult and need to be modified to suit some particular type of joint.

Jumaat (2008) tested double shear joints for Malaysian tropical timber made of Kempas, Mengkulang and Pulai and strengthened using 1.19 cm diameter steel bolts. They indicated that the failure mode of Kempas falls in range III or IV and EYM (EC 5) has underestimated the ultimate strength for bolted joints by up to 74% accordingly.

Joints using steel dowels has been established. However, the use of steel as fastener has its own disadvantages to the joint. Thus, there is a need to look at alternative materials. This study explored the potential of a glass fibre reinforced plastic (GFRP) rod as the dowel. Based on the discussion above, there are discrepancies in estimating the load-carrying capacities of timber joints using NDS and EC5 codes for steel fasteners. However, Wilkinson 1992 found that the 5% offset yield load is generally less variable than either the proportional limit or ultimate capacity. The use of 5% offset method is also somewhat subjective, it is believed to be a more accurate and repeatable method for determining joint strength than the use of the proportional limit or ultimate strength (Schmidt & Daniels 1999). Nonetheless, a majority of validation studies have been focused at the 5% offset yield level, with less consideration being given to behaviour at ultimate capacity. Therefore further research of connection behaviour at ultimate capacity is in need to validate the application of the general dowel equation at ultimate capacity (Finkenbinder 2007). For that reason, this study used NDS codes to investigate the load-carrying capacity of timber joints using GFRP dowels.

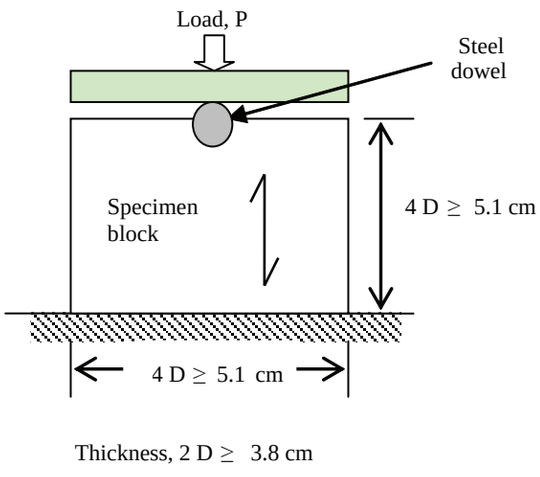
GFRP was introduced as a dowel in this study as it is well known for its benefits as having a high local force transfer, very stiff connections particularly when the dowels are loaded in the axial direction and good fibre properties. It is also a low cost material for production with improved aesthetics as the connections are completely hidden in the timber structure as well as being light weight conn ectors. A few recent studies of FRP composites in the form of sheets have been studied such as for their application on wood splice (Pantelides *et al*. 2010) and double shear joints (Hehl *et al.* 2009). Pantelides *et al*. (2010) found that the FRP composite material is an effective method and may enhance the tension capacity of wood splice connectors. Positive results have also been reported by Hehl *et al*. (2009) in the use of the adhesively bonded FRP composites for strengthening the double shear joints.

The specific objectives of this study were to determine the load-carrying capacities of timber joints with GFRP dowels and using EYM equation from NDS to estimate the load-carrying capacity of double shear joints strengthened with GFRP dowels. The dowel failure mode behaviour and performance after each test were also investigated and compared to the theoretical analysis.

RESEARCH METHODS

General

The yield limit model for dowel-type fasteners is based upon engineering mechanics and it uses connection geometry and material properties to evaluate strength. The primary factors used to compute the design value Z, as shown in Table 1, include fastener diameter, dowel



(a)

(b)

Figure 2. Dowel bearing test set-up: (a) Schematic diagram and (b) Actual test set up.

bearing length, dowel bearing strength of wood member and fastener bending yield strength. The dowel diameter and the thickness of member or the dowel bearing length in the study are fixed, i.e. 1.27 cm diameter and 1.17 cm, respectively. The next section describes the procedure to determine the bearing strength of wood and the dowel bending yield properties.

Dowel Bearing Strength Test Setup

The dowel bearing strength is the strength property of the member in a connection that resists embedding of a dowel. Dowel bearing strength tests were performed on Kempas wooden blocks using steel dowels in accordance to ASTM D5764-95: 'Standard test method for evaluating dowel-bearing strength of wood and wood-based composites'. Twenty three wooden blocks were prepared in the size of 4.1 cm × 9.5 cm × 12.5 cm parallel to the grain direction. In order to prepare the half-hole, two wooden blocks were clamped together with sufficient pressure to maintain contact between faces. A lead hole was then drilled in between the two pieces with a similar diameter to the dowel. Clamps were removed and the dowel was then put on the half hole. Both pieces were used for testing.

The testing assembly consisted of a rectangular wooden block with half-hole placed on the flat base on Universal Testing Machine (UTM) and a load head made of steel plate that pressed the dowel into the specimen. Dowel bearing configuration and test setup is shown in Figure 2.

The tests were run on a UTM hydraulic testing machine with a 102 tonne capacity load cell. A constant displacement rate of 0.1 cm/sec was used, and the tests were run until the load head touched the block or when the displacement remained constant. The resistance load was recorded from the load cell, and displacements were acquired from the external Linear Variable Displacement Transducer (LVDT). The load and displacement data were recorded by data requisition equipment.

The load versus displacement curves were plotted and by using this graph the yield load for the dowel bearing samples was determined with the 5% diameter offset method. Dowel bearing strength (F_e) from experimental tests was then determined by the following equation:

$$F_e = \frac{P_{0.05D}}{Dt} \tag{4}$$

where, $P_{0.05D}$ is the 5% diameter offset value from the load-displacement curve, D is the dowel diameter and t is the thickness of the specimens.

Bending Yield Strength Test Set up

The dowel bending yield strength was determined experimentally by using the 3-point bent test in accordance with ASTM F 1575 -03 as shown in Figure 3.

The current nail standard ASTM F1575-03: 'Standard Test Method for determining the bending yield strength for nails' is currently applicable to nails and not to dowels. Therefore in order to determine the dowel yield strength test for steel and GFRP dowel, the tests were modified according to ASTM F1575-03 standard. Steel and GFRP bending yield strength tests were conducted on 1.27 cm diameter dowels. The mild steel dowels came from a single domestic manufacturer and were drawn from the same batch to reduce the variability of the test population. The dowels were with a full body diameter,

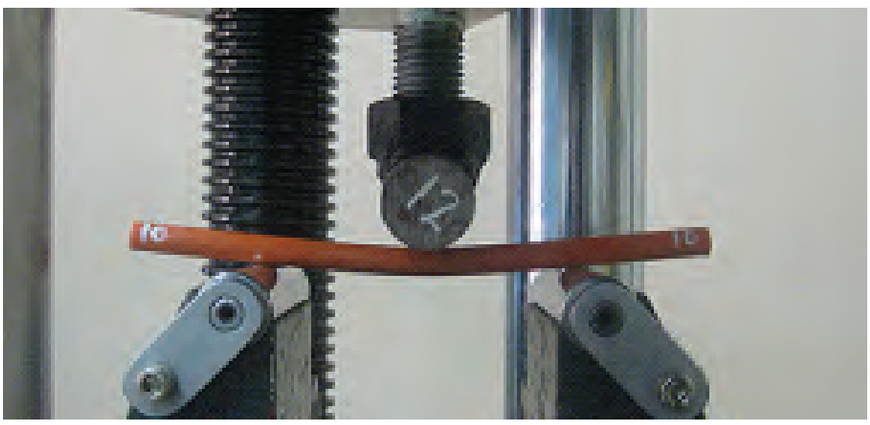


Figure 3. Three-point bending test set up.

without threads. The yield moment, F_{yb} was determined based on the 5% diameter offset method as stated by Equation 5:

$$F_{yb} = \frac{M}{S_p} = \frac{3P_y s_{bp}}{2D^3} \quad (5)$$

where M is the bending moment in dowel; S_p is the plastic section modulus for dowel; S_{bp} is the spacing of bearing points and D is the dowel diameter.

Double Shear Strength Test Set Up

Double shear single-dowel joints parallel to the grain were tested to determine the ultimate capacities of the joints. The ASTM Standard D 5652 – 95 (re-approved 2007) was used to prepare the double shear joint experiments. The joint specimens consisted of three wood members connected with one dowel prepared using Kempas. Each wood specimen was assured to be clear from any defect, essentially clear and straight-grained. The dimensions of the middle (main) and side specimens were in one similar size, that is 4.1 cm × 10 cm × 21.5 cm. Two types of dowel, that is steel and GFRP, were prepared in the same 1.27 cm diameter with 12.6 cm length. Mild steel dowels were prepared by local manufacturer whilst GFRP was ordered off the shelves from United Kingdom manufacturers. A total of sixteen double shear joints were prepared. Seven joints were fastened with steel dowels while 9 joints were fastened with GFRP dowels. All test specimens were stored at 20±3ºC and 65±2% relative humidity prior to testing.

The tests were run using a 102 ton Universal Testing Machine. Two linear voltage displacement transducers (LVDT) were mounted at the main member and one of the side members. Load was applied to each joint which was griped at the bottom of the specimens using a hand operated hydraulic pump. The applied loading was captured using a load cell and all data logged to a computer. Figure 4 shows the test set up.

Due to the fact that these studies were conducted to investigate the validity of the model at yield and the performance outcome from different dowel material, all connections were run up to total failure. Total failure was when the double shear connections were totally disconnected either caused by the failure in dowel, side member or main member failure. Testing was loaded and continued until a fracture occurred that was accompanied by a substantial non-recoverable drop-off in load. Ultimate

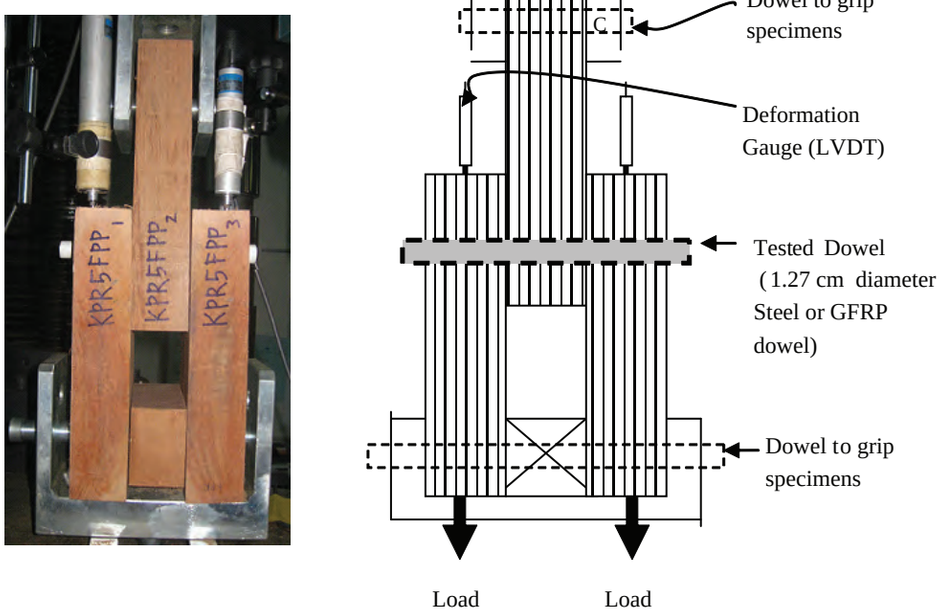


Figure 4. Experimental set-up for double shear connections parallel to grain in tension (a) Actual test set up and (b) Schematic diagram of test set up.

shear strength and yield load were then recorded. The rate applied for this study was 0.03 cm/min. All tests reached its maximum loading within 5 and 20 min as required by ASTM D 5652–95 standards. The characteristics of joint elements such as the failure mode, tension splitting failure and tear out failure were noted and observed for each replicate.

Moisture content of the specimens was determined by oven dry method. The moisture content specimens were the double shear test specimens after the tests were completed. Density was calculated based on the mass and volume at the time of test. The results obtained from dowel bearing strength and dowel bending strength were used together with the data obtained from this test to determine the double shear joint's capacities and later, compared with the strength as estimated using NDS theory.

RESULTS AND DISCUSSION

Dowel Bearing Strength

Dowel bearing strength (*Fe*) is the property of wood that affects the nominal design value for a single fastener subjected to lateral shear load. It is associated with the crushing strength of a wood member under loading from a dowel. The dowel bearing strength of a member depends on the relative size of the dowel and the specific gravity of wood. The angle of load to grain also affects the dowel bearing strength for large-diameter fasteners. However in this paper, only the effect of load in the direction parallel to grain was reported. It was found that the average density of Kempas at tests was 0.04 lb/in^3 and the dowel bearing strength of Kempas, *Fe*, was 14 726.11 psi (COV= 9.9%). This information would be used later in the estimation of double shear joint strength.

Bending Yield Strength

The yield load capacities were computed using the 5% diameter offset from the load-displacement curves. Results of the bending yield strength of dowels are given in Table 2.

Table 2. Results of experimental dowel bending strength.

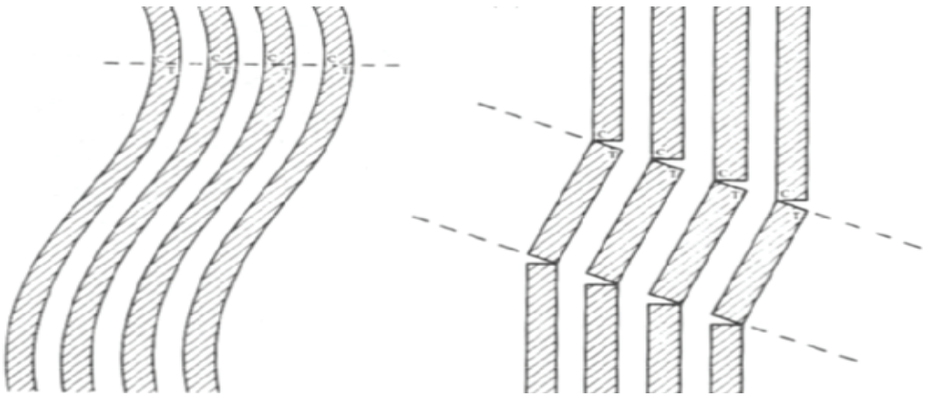
Type of dowel	Bending yield strength (F_{yb}) (psi)	COV (%)
Steel	13 062.08	3.1
GFRP	6839.39	17.3

It can be seen that steel dowels had a higher bending strength compared to GFRP dowels. Dowel bending yield strength of steel was almost double (47.64%) that of GFRP bending yield strength, respectively. It was also observed that the variability in the dowel bending yield strength of GFRP was higher than that of steel. GFRP is a composite of glass fibre bonded with resin while steel is a more homogenous material. Under bending, the failure of fibre causes tensile and compression stress across the fibre due to in-phase buckling as shown in Figure 5a. Brittle fibre e.g. carbon fibre, form two planes of fracture as shown in Figure 5b. This might explain the high variability in the bending yield strength of GFRP. Later these values were used to determine the estimated double shear joint using the NDS (2005).

Double Shear Strength

Table 3 shows the summary of the results obtained.

Based on the theory of the yield limit model when the side and main member were of a similar thickness and species,



(a) (b)

Figure 5. (a) Phase buckling leading to kink zone and (b) Two planes of fracture from failure of carbon fibres (Hull 1991).

equations I_m and I_s do not have any different parameters to differentiate the capacity of joint. Thus the value of the dowel bearing strength will not affect the load-carrying capacity of the joint. However for equations IIIs and IV, the load carrying capacity of the joint is differentiated by the dowel bending yield moment parameters.

It was found that the minimum load-carrying capacity of double shear members strengthened with steel and GFRP dowel computed based on NDS was 454 kg and 328.5 kg, respectively and both were categorised in failure mode IV. This result was the minimum of all computed calculations, and therefore accepted as the estimated failure load-carrying capacity for each joint.

The experimental results obtained showed that the joint strengthened with a steel dowel attained a higher load-carrying capacity then when strengthened with a GFRP dowel. The stiffer behaviour of steel and its homogenetic material properties as described in previous section made it possible to carry 28% extra loading compared to a joint fastened with GFRP dowel. The differences of calculated and experimental results for joints strengthened with steel dowel and GFRP dowel to the 5% offset load of the experiment were found to be 73% identical (Figure 6).

This finding supports the results reported by Jumaat *et al*. 2008 where the EYM (EC 5) underestimated the strength of bolted joints up to 74%. The failure mode experimental joint strengthened with steel dowel was found in range IIIs (Figure 7) which is higher than the theoretical mode IV. However the experimental failure mode of joint strengthened with GFRP dowel supports theory when it falls in the same mode, i.e. mode IV (Figure 8).

CONCLUSION

The estimated double shear strength of GFRP and steel dowelled joints were calculated using the experimental results of bearing strength of Kempas and the dowel yield strength. The estimated and the experimental double shear strength were analysed. As a conclusion, it was shown that the NDS (2005) was capable of predicting the load-carrying capacity of double shear joints strengthened with GFRP dowel as well as successfully predicted the failure mode behaviour of the joints.

Table 3. Comparison of double shear test using experimental works and NDS (2005).

Type of dowel	Experimental			NDS (2005)		
	Sample code	Ultimate load capacity (lbs)	5% diameter offset load (lbs)	Failure mode	Equation No./ failure mode	Load capacity (lbs)
Steel	S1	4428.74	3900.43	III_s	I_m	2376.80
	S2	3630.67	3109.11	III_s	I_s	4753.59
	S3	3718.34	3671.13	III_s	III_s	2064.09
	S4	4217.42	3808.26	III_s	IV	1000.92
	S5	3898.19	3507.02	III_s		
	S6	3774.54	3774.54	III_s		
	S7	4466.95	3884.70	III_s		
	Average	4019.26	3665.02	III_s	Min : IV	1000.92
	SD	347.24	279.95			
	CV	0.09	0.08			
GFRP	G1	2992.21	2616.78	IV	I_m	2376.79
	G2	2776.40	2416.70	IV	I_s	3238.59
	G3	3133.846	2882.05	IV	III_s	2074.59
	G4	2882.05	2544.84	IV	IV	724.27
	G5	3138.33	2182.89	IV		
	G6	3967.88	2893.29	IV		
	G7	2585.30	2580.81	IV		
	G8	3106.86	3007.94	IV		
	G9	2733.68	2654.99	IV		
	Average	3035.17	2642.25	IV	Min. : IV	724.27
	SD	400.16	257.44			
	CV	0.13	0.10			

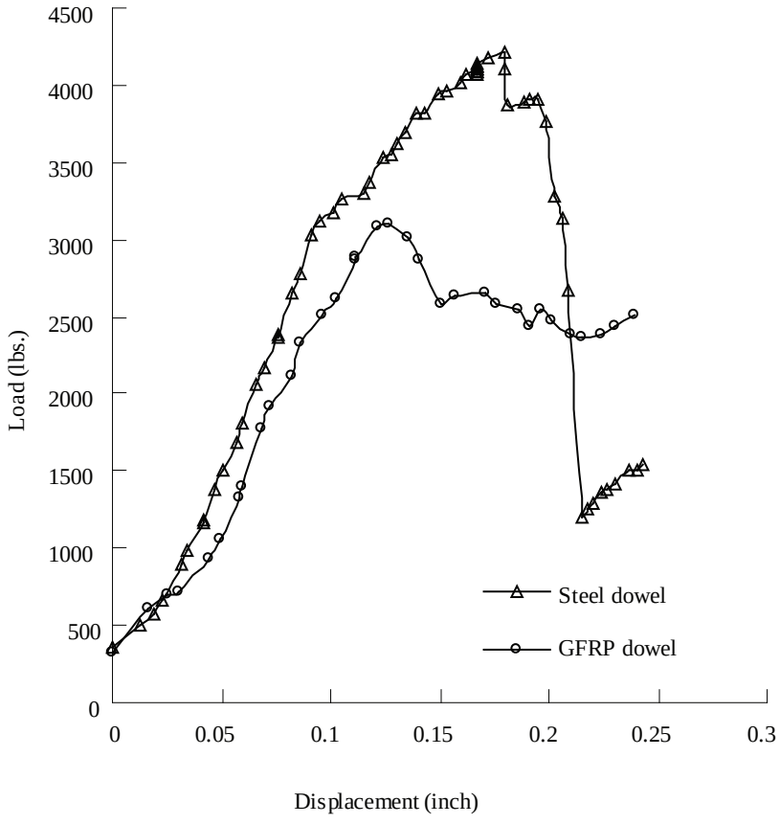


Figure 6. Typical load vs displacement curve of steel and GFRP dowel showing position of the predicted (EYM) and experimental capacity (5% offset load and ultimate load).

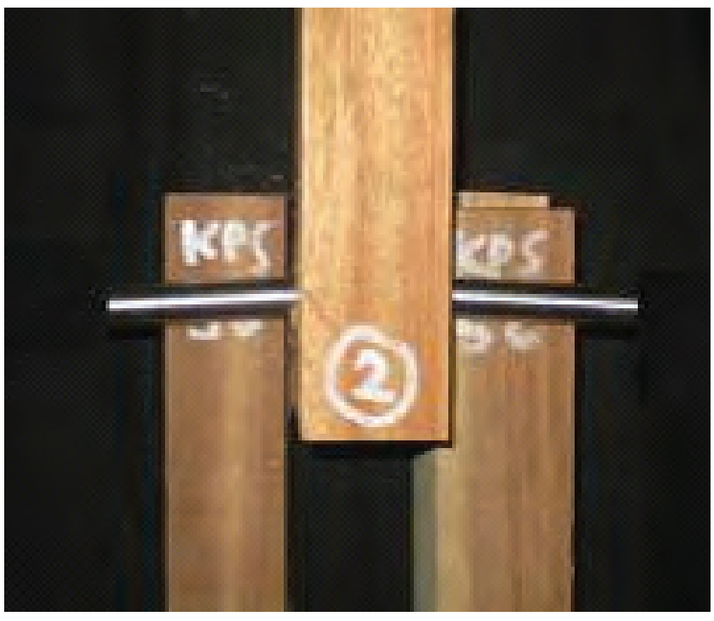


Figure 7. Double shear joint after test — failure mode III_s for steel dowel.

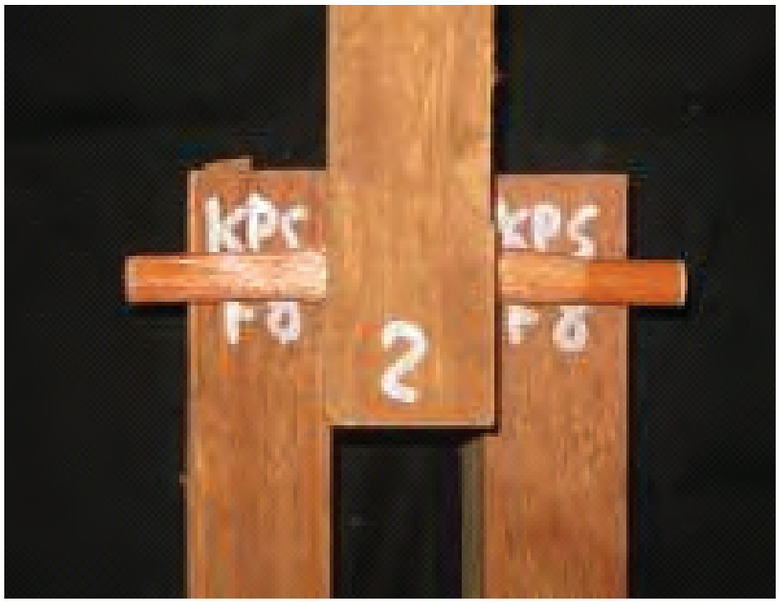


Figure 8. Double shear joint after test — failure mode IV for GFRP dowel.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Science, Technology and Environment, Malaysia for funding the project through FRGS, UiTM.

Date of submission: January 2011
Date of acceptance: May 2011

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ASM Sci. J., **5(1)**, 11–18

Effects of Lubrication in Warm Powder Compaction Process

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Warm compaction is an advanced manufacturing technique which consists of two consecutive steps, i.e. powder compaction at above ambient temperature and sintering in a controlled environment. Due to the relative movement between the powder mass and die wall as well as sliding among powder particles, frictional force is generated during the compaction stage. Admixed lubricant is used during the compaction step in order to minimize friction and hence improve the uniformity of the density of distribution inside the component. However, during the sintering process, trapped lubricant is often found to be burnt out hence leaving pores or voids which result in the lower strength of the final products. Warm compaction was initiated in the nineties, however not much information has been published about the effects of lubrication on the quality of the components produced through this route. Therefore, this paper presents the outcome of an experimental investigation about the effects of lubrication on manufacturing near-net shape components through the warm compaction route. Iron powder ASC 100.29 was mixed mechanically with zinc stearate to prepare the feedstock. Mixing time, weight percentage of lubricant content and compaction temperature were varied during green compact generation while sintering temperature, heating rate and holding time were manipulated during sintering. The relative densities and strengths of the final products were investigated at every compaction as well as sintering parameter. The results revealed that lubrication could provide significant effects at the compaction temperature of 180ºC while no significant effect of lubrication was observed during sintering. The suitable lubricant content was found to be 0.4 wt% and mixing time was around 30 min and the sintering temperature was around 990ºC.

Key words: Warm compaction; green compact; lubrication; density; strength; sintering; density; friction; full cycle; mixing time; heat; cooling; rate

Powder compaction is defined as production of solid components from metal powder through compaction at room temperature or at elevated temperature and subsequently sintering the green compacts in a controlled environment (Whittaker 1990). Products produced through this route are used in a wide range of industries such as in automotive, aerospace, power tool and household appliances. It has been identified that a significant number of engineering components and parts are made through this route which has been existence since the early 1900s. This processing technique is the better technology for production of mechanical components with a higher precision than other production technologies (Yamaguchi et al. 1997; Bocchini 1999; Ariffin *et al*. 2001).

During powder compaction, densification occurs due to the application of axial force, hence every particle of the powder mass moves in the direction of applied load. The powder particles also have to move along the die wall under the increasing force. Both phenomena during compaction generate friction, i.e. inter-particle and die-wall frictions (Ariffin *et al*. 2003; Bocchini, *et al*.1996; Nor *et al*. 2008; Rahman *et al*. 2011), which further generate heat (Rahman *et al*. 2006) and cause inhomogeneous particle distribution. These result in inhomogeneous density distribution inside the green compacts (Kanno *et al*. 2006) that lead to crack initiation during the ejection of green compacts from the die cavity (Sydney 1997). Therefore, in order to reduce this problem, lubricant must be added inside the powder mass or/and is applied to the die wall.

The lubricant content and feedstock preparation have significant influence on the sintered properties of the products because the main powder constituent has a higher density than the lubricant. However, the main function of the lubricant is to increase the re-arrangement of the powder particles (Vidarsson *et al*. 2006). Large amounts of lubricant inside the green compact, generally occupy more pores which affect the density and strength of final products (Deepak & Diran 2002). Furthermore, the shrinkage which is related to dimensional tolerance, electrical conductivity, as well as surface finish are in direct relation to the porosity (German 1990) contributed by the lubricant that vaporizes during sintering.

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Higher density green compacts give a larger total contact area to the particles, thus improving bonding between the metal powders during the sintering process. The densification during green compact generation is related to the compaction load, temperature and amount of admixed lubricant. The bonding process is enhanced by the crystal lattice caused by plastic deformation but entrapped lubricant provides contradictions which can change the mechanical properties and microstructures during the sintering process (Hoganas 1997). The objective of this paper is to present the results of a comprehensive research study on the full cycle of powder compaction process. The study investigated the parameters involved, i.e. lubricant content, mixing time, compaction load and temperature, sintering temperature, holding time, heating rate and cooling rate.

EXPERIMENTAL PROCEDURE

Iron powder ASC 10.29 was used as the main powder constituent while zinc stearate ($C_{36}H_{70}O_4Zn$) was used as lubricant. The as-received powder had the particle size range of 20 µm – 180 µm. The powder manufactured by Höganäs AB Company had the composition of 1.5% Cu, 0.5% Mo, and 4% Ni balanced with Fe. The feedstock was prepared by mechanically mixing the main powder constituent with the lubricant using a low-speed mixer. Two different percentage weights of zinc stearate, i.e. 0.4 wt% and 0.8 wt% were used. Three mixing times, i.e. 10, 30 and 60 min were used to study the effects of mixing in generating crack-free green compacts. A solid cylindrical shaped die with a radius of 10.35 mm and a length of 60 mm together with top and bottom punches was attached to the T-15 compaction rig. Four point heaters (50 Watt each) were attached to the die for heating the powder mass as well as the die assembly.

Two compaction temperatures were examined which were 120ºC and 180ºC, for the green compact generation. The powder mass, the die assemblies with top and bottom punches were heated up to the required temperature and held there for 30 min prior to compaction, in order to get a uniform temperature distribution. The multi-axial compaction was conducted simultaneously by applying a 130 kN load. On reaching the desired value, the top punch was released to its initial position while the bottom punch ejected the green compact out of the die. Three sets of experiments were conducted in order to achieve greater accuracy, hence minimizing experimental error.

The green compacts generated through the warm compaction process were further heat treated through sintering in an argon gas fired furnace with parameters that ranged from sintering temperatures of 900ºC and 990ºC with heating rates of 5ºC/min and 10ºC/min. The sintering time was kept at a constant value of 30 min. The sintered products were tested for their bending strengths using the universal testing machine 5T- Instron 5567 with serial number P4716. The compact was held tightly at both ends while a transverse force was applied at the middle of the compact. All data such as elongation, maximum stress and maximum strength were collected through the data acquisition system in the computer until the compact fractured or broke down. The densities and dimensional changes were measured using weighing balances and digital vernier calipers, respectively. The measurements were repeated five times and multiple locations were selected for measuring sample lengths and diameters.

RESULTS AND DISCUSSIONS

As reported previously (Hoganas 1998), green density was found to be higher for the compaction at 180ºC (Figure 1). This was due to the softening behaviour of metal powder at this range of temperature so that the iron powder particles could be displaced more easily from their initial positions and good re-arrangement of the packing order could occur (Rahman *et al*. 2010). Furthermore, iron particle re-arrangement was improved due to less friction amongst iron particles due to the presence of lubricant. Higher amount of lubricant led to density improvement. However, at 180ºC compaction temperature, green density tended to decrease. This could be due to the lower melting temperature of zinc stearate which is 130ºC. However, the reduction in density was minimal, yet still higher than the green compact without lubricant. This implied that zinc stearate could also function in a liquid phase during compaction.

The effect of mixing time on the relative densities of green compacts with different lubricant content is shown in Figure 2. For both lubricant content, i.e. 0.4 wt% and 0.8 wt%, 30 min of mixing time could produce green compacts with high relative density. This phenomenon indicated that mixing time was a significant parameter during feedstock preparation for obtaining higher relative density.

Figure 3 shows the variation of green strength with respect to lubricant content for the compaction temperatures of 120ºC and 180ºC. Differences in density and strength were observed with respect to compaction temperature as shown in Figure 1 and Figure 3. These results showed that green strength differed from green density at compaction temperatures above 150ºC. The behaviour of iron powder at this temperature could be related to the cold working phenomena where mechanical bonding which was related to strength, was increased for compaction at a lower temperature. Due to heating up of the powder mass, iron particles became irregular in shape. Therefore, at the compaction stage, the sliding tendency of lubricant became limited hence stronger yet lighter green compacts were generated (Shackelford 2000).

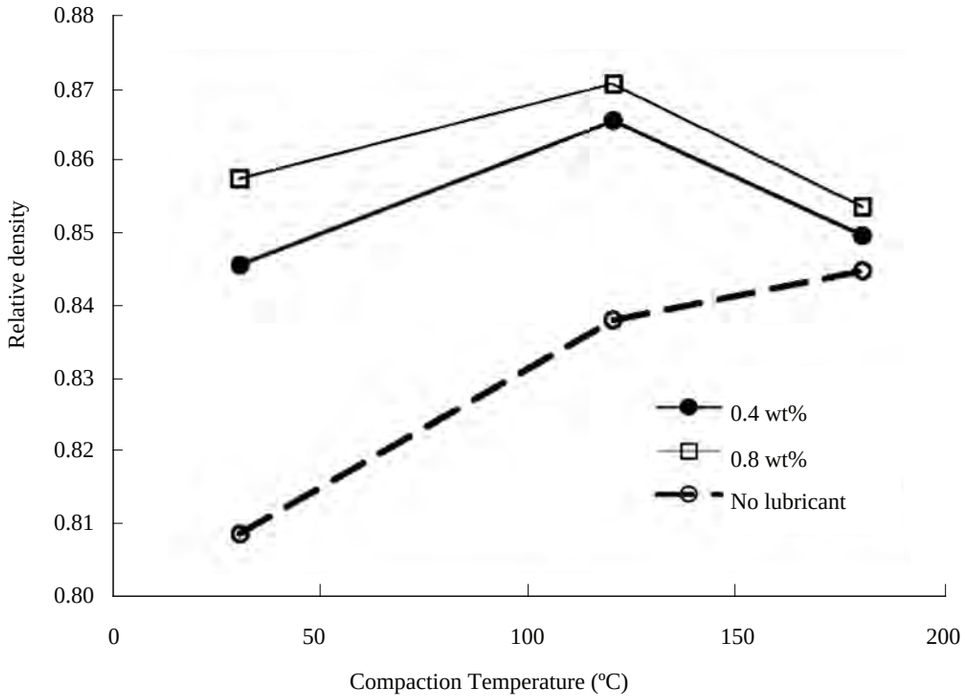

Figure 1. The effect of compaction temperature on green density.

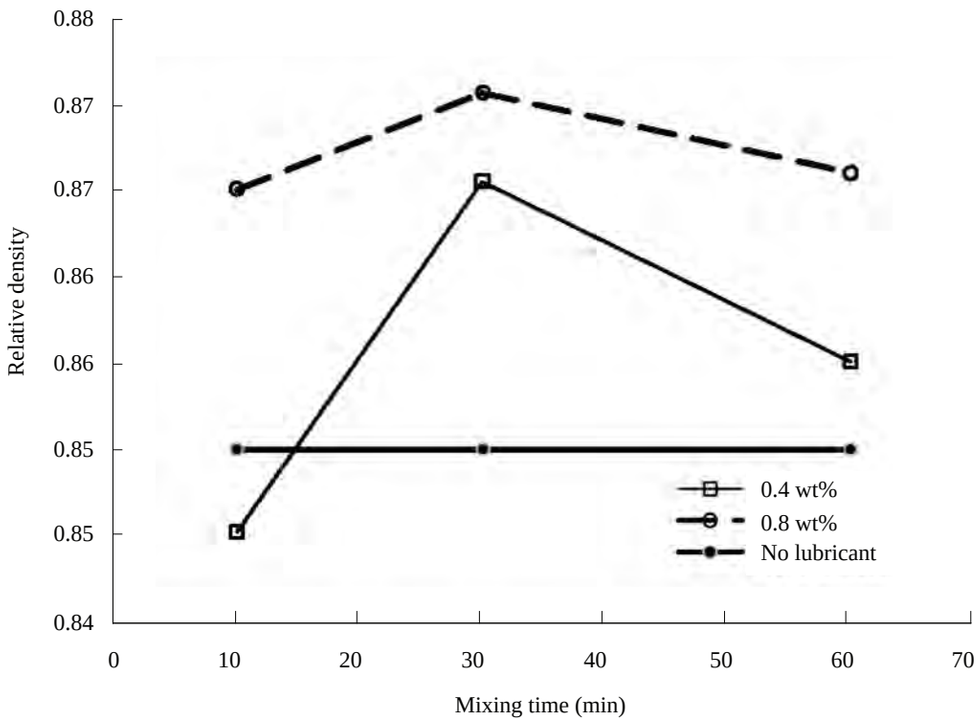

Figure 2. The effect of mixing time on green density.

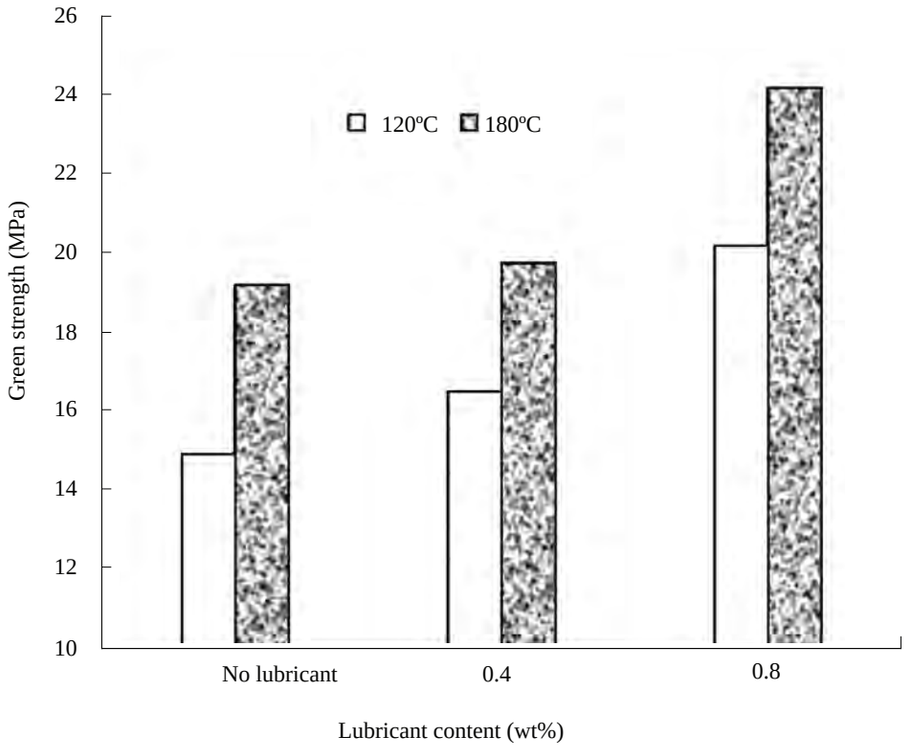

Figure 3. The effect of lubricant content on green strength.

Figure 4 shows that mixing time had a significant effect on the green strength of the compact. It was evident that higher amounts of lubricant could still produce compacts which had better green strength. Figures 5 and 6 show the effect of sintering temperature and the heating rate for the 30 min sintering time on the density of sintered products. It could be seen that samples generated without lubricant had a lower density compared to samples with admixed lubricant, regardless of the sintering schedules. As they were more compact and minimal lubricant was trapped inside the samples (due to proper mixing), samples with admixed lubricant had the upper hand in increasing the density during compaction process. The lower density observed at the faster heating rate was due to less pore elimination caused by slower grain growth as compared to the slower heating rate (Rahman *et al*. 2010).

Figure 7 shows the strength variation at different sintering temperatures. It can be observed that higher sintering temperatures produced compacts having higher strength. Generally, higher density green compacts had a larger total contact area amongst at the particles, thus there was improved bonding between the metal powders during the sintering process. At higher sintering temperatures, structural recrystallization occured steadily and the fusion rate among iron powder particles was increased. At higher temperatures, more pores also became spheroid which weakened the particles fusion. Less pores trapped inside the sample might also be the reason to increase the strength of sample without lubricant (Babakhani 2006).

The percentages of swelling and shrinkage measured after the sintered components reached room temperature are presented in Table 1. It was evident that products with admixed lubricant formed at 180ºC had good dimensional stability. Swelling occured in 0.2% to 1.4% of samples regardless of the amount of lubricant and also the sintering schedules. It could be stated that, the major influence in this minimum swelling with the presence of lubricant, was the effect of mixing time. The maximum amount of lubricant had been forced out from the powder mass during compaction due to the efficient mixing time. Therefore, later in the sintering stage, the samples with admixed lubricant had minimal porosity which lowered the phenomena of swelling or shrinkage during vaporization of lubricant (Simchi 2003).

CONCLUSION

This study found that a limited amount of admixed lubricant during warm forming can minimize interparticle and die-wall friction, this could hence improved the mechanical properties of green compacts. However, the lubricant is

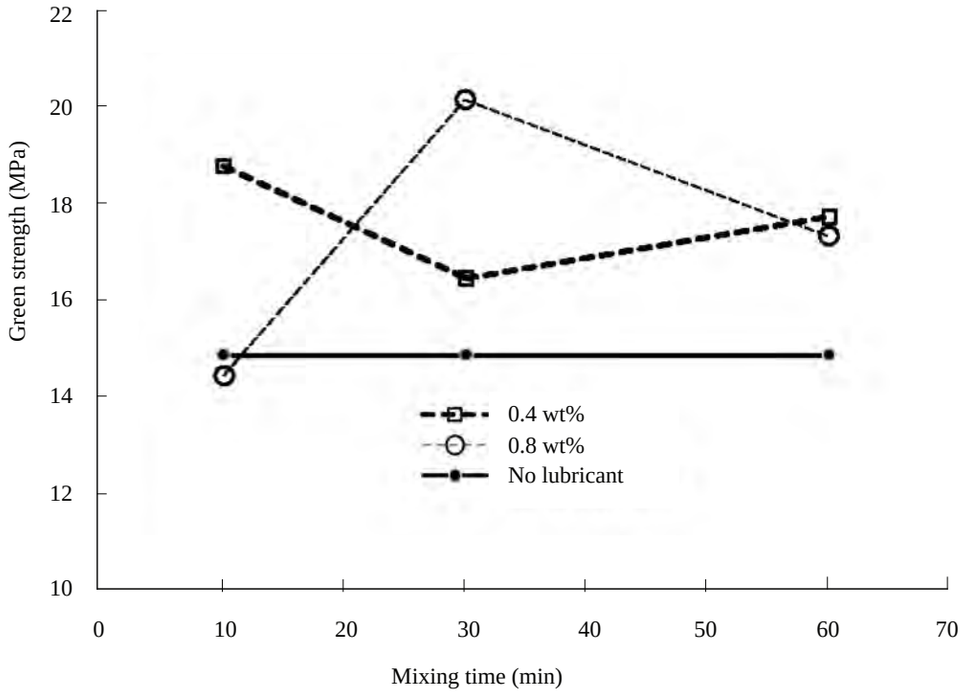

Figure 4. The effect of mixing time on green strength at 120°C compaction temperature.

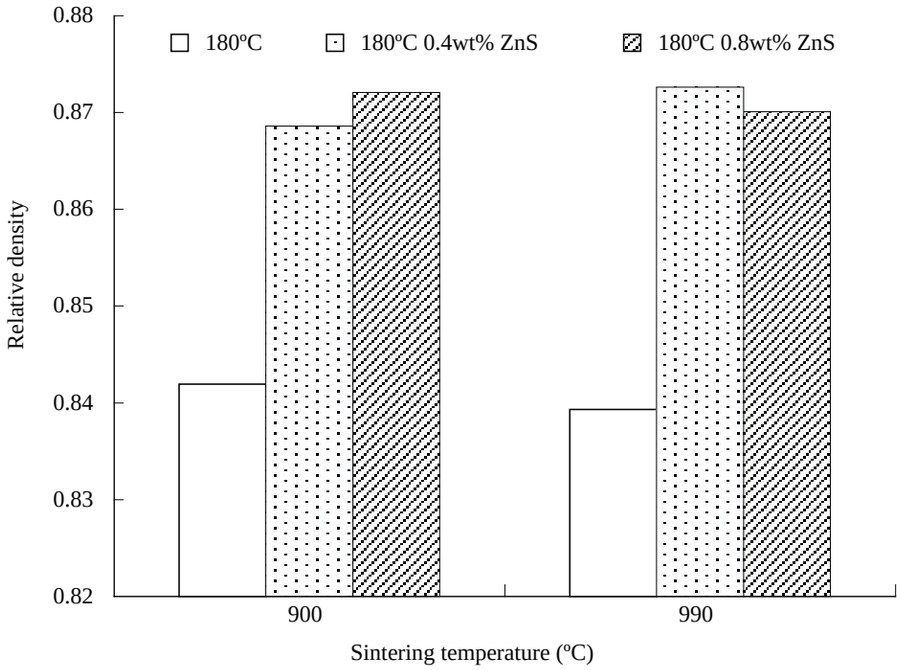

Figure 5. Relative density at 5°C/min heating rate and 30 min sintering time.

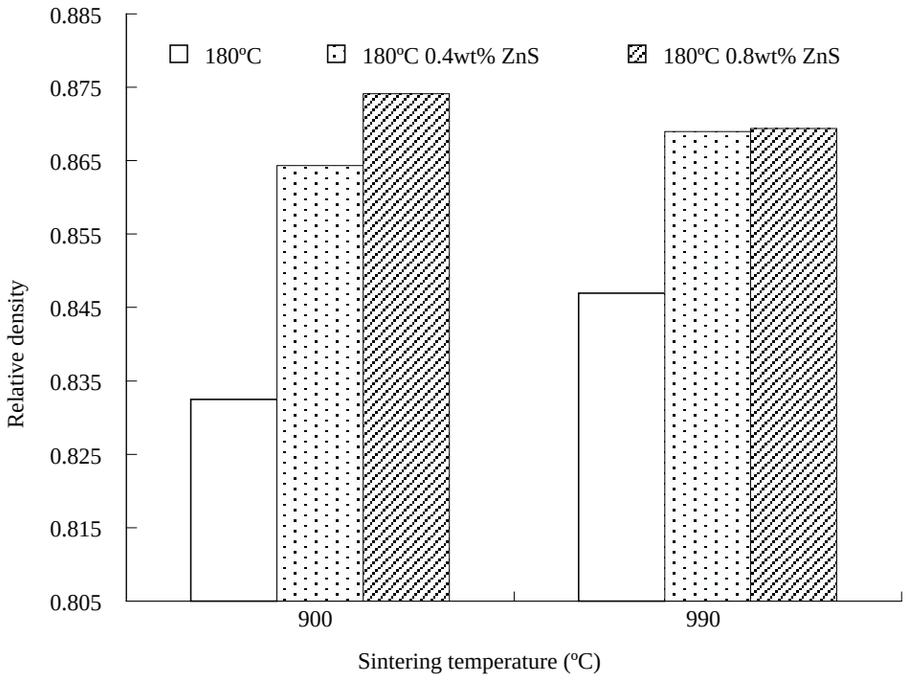

Figure 6. Relative density at 10ºC/min heating rate and 30 min sintering time.

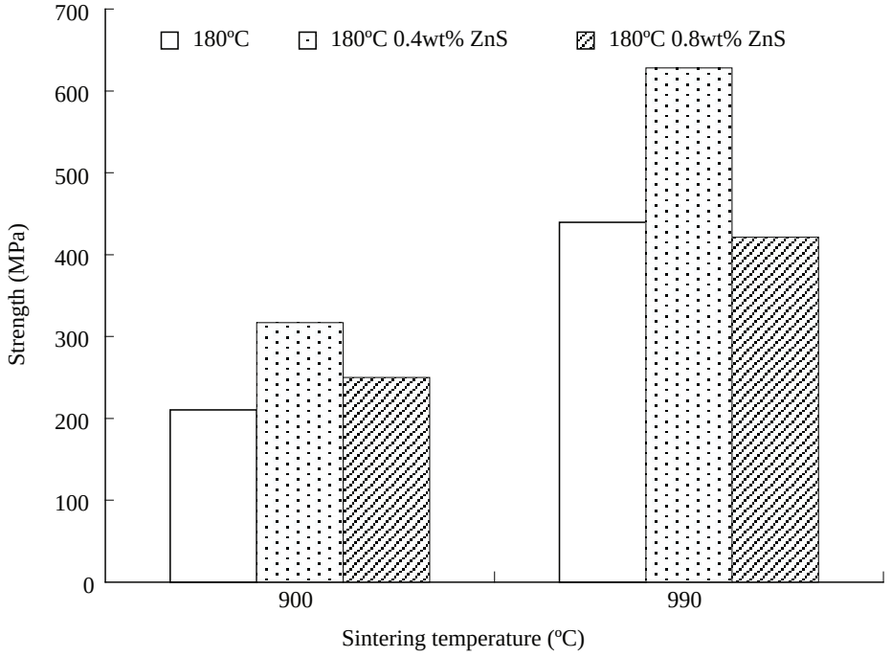

Figure 7. Strength of sintered products for 10ºC/min heating rate and 30 min sintering time.

Table 1. Dimensional changes of sintered products for different sintering schedules.

(a) Sintering temperature: 900ºC; Heating rate: 5ºC/min; Holding time: 30 min

Sample	Swelling (%)	Shrinkage (%)
180ºC	–	0.4519
180ºC 0.4 wt% ZnS	0.6099	–
180ºC 0.8 wt% ZnS	0.2743	–

(b) Sintering temperature: 990ºC; Heating rate: 5ºC/min; Holding time: 30 min

Sample	Swelling (%)	Shrinkage (%)
180ºC	–	1.2875
180ºC 0.4 wt% ZnS	1.1079	–
180ºC 0.8 wt% ZnS	0.6994	–

(c) Sintering temperature: 900ºC; Heating rate: 10ºC/min; Holding time: 30 min

Sample	Swelling (%)	Shrinkage (%)
180ºC	–	0.6687
180ºC 0.4 wt% ZnS	0.9026	–
180ºC 0.8 wt% ZnS	1.0075	–

(d) Sintering temperature: 990ºC; Heating rate: 10ºC/min; Holding time: 30 min

Sample	Swelling (%)	Shrinkage (%)
180ºC	–	1.5391
180ºC 0.4 wt% ZnS	1.1347	–
180ºC 0.8 wt% ZnS	1.1396	–

required to be mixed for a certain duration of time, i.e. 30 min for producible results. The suitable compaction temperature was found to be around 180ºC. The sintering temperature was found to be 990ºC for a holding time of 30 min. Near-net shaped mechanical components can be produced through this method of manufacturing.

ACKNOWLEDGEMENT

The authors want to thank Ministry of Science, Technology and Innovation Malaysia for funding this research study under 03-02-03-SF0146.

Date of submission: January 2011
Date of acceptance: September 2011

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Conductivity and FTIR Studies of Low Molecular Weight Polyvinyl Chloride-based Polymer Electrolytes

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In this present study, a series of polymer electrolyte thin films were synthesized by incorporating different ratios of lithium triflate ($LiCF_3SO_3$) in a low molecular weight polyvinyl chloride (PVC) matrix by the solution casting technique. The incorporation of $LiCF_3SO_3$ suppressed the high degree of crystallinity in PVC enabling the system to possess an appreciable ionic conductivity. The ionic conductivity of the samples, with different $LiCF_3SO_3$ content, was determined by the aid of AC impedance spectroscopy. The highest ionic conductivity of 4.04×10^{-9} S cm^{-1} was identified for the composition of PVC: $LiCF_3SO_3$ (75:25). Further understanding of the ionic conductivity mechanism was based on temperature-dependent conductivity data which obeyed Arrhenius theory, indicating that the ionic conductivity enhancement was thermally assisted. The possible dipole-dipole interaction between the chemical constituents was confirmed with changes in cage peak, analysed using Fourier transform infrared spectroscopy.

Key words: PVC; $LiCF_3SO_3$; FTIR; complexation; films; low molecular weight; crystallinity; ionic; conductivity; temperature-dependent; dipole-dipole interaction

Polymer electrolytes are one of the enhancements done by researchers as replacements to the present liquid lithium electrolytes. Beside their outstanding thermal and mechanical stability, flexibility, light weight and thin forming properties, polymer electrolytes do have wide applications as solid electrolyte in various electrochemical devices such as batteries, photochemical solar cells, sensors, fuel cells, electrochromic display devices and supercapacitors (Do *et al.* 1996; Reddy *et al.* 1999; Lewandowski & Stepniak 2001).

An initial work on producing polyvinyl chloride (PVC) blend polymer electrolytes was unable to meet the required criteria and standard as a good applicable conductor (Watanabe *et al.* 1981). In line with this matter concerned, an effort was later evolved with an idea of increasing the ionic conductivity value of PVC-based polymer electrolytes by using the single solvent method (Alamgir & Abraham 1993).

The analyses of polymer electrolytes were essentially focused on increasing the ionic conductivity at room temperature. Various methods were carried out to meet this objective such as the addition of plasticizers, the combinations of polymer and salt with different characteristics, addition of higher salt concentrations and others.

In this paper, the conductivity and complexation of PVC as a host polymer for polymer electrolytes was studied. PVC was chosen because it is one of the most inexpensive commercially available polymers and can easily blend with a variety of salts and plasticizers. This study involves synthesizing polymer electrolytes of PVC complexed with $LiCF_3SO_3$ salt. The ascendancy of $LiCF_3SO_3$ salt concentration in the polymer blend complexes was investigated. The phase structure and complexation of the polymer blend complexes were studied by using the FTIR method.

EXPERIMENTAL

Low molecular weight PVC with an average molecular weight of 48 000 g/mol (Fluka), lithium trifluoromethanesulfonate or lithium triflate ($LiCF_3SO_3$) with an average molecular weight of 156.01 g/mol (Fluka) and tetrahydrofuran (THF) (J.T. Baker) were used for the preparation of the polymer electrolytes. The thin films of PVC-based polymer electrolytes were prepared using the solution cast technique. The complexed films, composed of PVC with $LiCF_3SO_3$, were synthesized with the following weight percentage ratio's (90:10), (85:15), (75:25) and (70:30), respectively by using THF solvent. Before preparing the polymer electrolytes, the $LiCF_3SO_3$

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salt was dried at 100ºC for 1 h in order to eliminate trace amounts of water in the material.

The weighed amounts of PVC and $LiCF_3SO_3$ were dissolved in THF and the solutions were stirred for 24 h in order to obtain a homogenous solution. The homogeneous solution was then cast on a Petri dish through the evaporation of THF in the fume hood with facial tissue covering it. This procedure yielded a free standing and mechanically stable film. The obtained thin films were then left in the desiccator to eliminate traces of water on the surface of the films.

The ionic conductivity studies were performed by sandwiching the thin polymer electrolyte film with a specially designed stainless steel film holder. The holder was connected to a HIOKI 3532 LCR Hi-tester impedance spectroscopy bridge interfaced to a computer for data acquisition over frequencies ranging from 50 Hz to 1 MHz within an interval time of one second. The complexations between PVC and LiCF3SO3 were determined by analyzing all the functional groups that were present in the FTIR spectrum. All the spectra were recorded over the wavenumbers ranging from 400 cm^{-1} to 4000 cm^{-1} with the resolution of 4 cm^{-1} and 1 cm^{-1} interval using the Perkin Elmer FTIR Spectrometer spectrum RX1.

RESULTS AND DISCUSSION

Conductivity Studies

The ionic conductivity of PVC-based polymer electrolytes were determined by varying the percentage weight of $LiCF_3SO_3$ doped into them. The conductivity values of the PVC: $LiCF_3SO_3$ polymer electrolytes were determined by the impedance measurements of the complex over a range of frequencies. Figure 1 shows the impedance plots (of Z imaginary versus Z real) obtained for pure PVC, PVC: $LiCF_3SO_3$ (85:15) and PVC: $LiCF_3SO_3$ (75:25). The shapes of the impedance plots display typical impedance behavior by showing a low frequency spike (residual tail) and a portion of semicircle at high frequency.

As seen in Figure 1, when the percentage weight of $LiCF_3SO_3$ increases, the intercept of the bulk resistance value decreases and shifts towards the origin, which was determined by the extrapolated depressed semicircle of the impedance plots. The conductivity values of the polymer electrolytes were calculated based on the equation:

$$\sigma = l/R_bA \quad \ldots 1$$

where, σ is the conductivity value, l is the thickness of the polymer electrolyte film, R_b is the bulk resistance of the electrolyte film and A represents the cross-section area of the electrolyte film. Thus, it could be assumed that as the percentage weight of $LiCF_3SO_3$ increased, the conductivity values increased as the R_b value was inversely proportional to the conductivity value. However, as we progressed into the conductivity studies on PVC: $LiCF_3SO_3$ polymer electrolytes, the conductivity values decreased with increased $LiCF_3SO_3$ salt content.

The conductivity values for a series of PVC: $LiCF_3SO_3$ based polymer electrolyte films with concentrations of $LiCF_3SO_3$ ranging from 0 wt.% to 30 wt.% are shown in Figure 2. Refering to the conductivity plots, the maximum ionic conductivity value was observed for sample PVC: $LiCF_3SO_3$ (75:25) with a calculated value of 4.04×10^{-9} S cm^{-1}. This was attributed to the increase in the number of free mobile ions (Ali *et al*. 1998). The conductivity value fluctuated initially before it increased at PVC: $LiCF_3SO_3$ (85:15). This was because the lithium salt did not mix appropriately with the PVC during the blending process. As the concentration of $LiCF_3SO_3$ salt increased, the build up of charge carriers was offset by the retarding effect of ion aggregates such as ion pairs which caused ionic constraints in both the ionic and polymer segmental mobility. Hence, for PVC: $LiCF_3SO_3$ (75:25) polymer electrolyte film, the conductivity reached a maximum value because of the two opposing forces, which were the increase in the number of charge carrier ions and the decrease in ionic mobility. The decrease in the ionic conductivity value when the ratio of PVC to $LiCF_3SO_3$ salt reached 70:30, was induced by the restricted ionic and polymer segmental mobility in a rigid matrix (Rajendran *et al*. 2003; Linford 1987).

Figure 3 shows the impedance plots for PVC: $LiCF_3SO_3$ (70:30) at two different temperatures (343 K and 363 K). It can be observed that with increasing temperature, the size of the depressed semicircle at the high frequency region and the spike from the interfacial effects at low frequency decrease as expected. Therefore, the R_b value (intercept of Z real axis) of the impedance plot decreases causing the conductivity value to increase.

The temperature dependent conductivities for temperatures ranging from 308 K to 373 K for the three samples were analyzed. Figure 4 shows the temperature (T) dependence conductivity for the three polymer electrolyte samples with $LiCF_3SO_3$ salt concentrations of 20 wt.%, 25 wt.%, and 30 wt.%. It can be seen that all the plots lie on a straight line (linear correlation coefficient ranges from 0.97 to 0.98), indicating that the plots obey Arrhenius rule:

$$\sigma = A_o \exp(-E_a/RT) \quad \ldots 3$$

where, E_a is the activation energy, R is the gas constant and A_o is the pre-exponential factor (Armand 1987).

FTIR Studies

FTIR studies were carried out to investigate the changes in the polymer matrices because they were sensitive to the

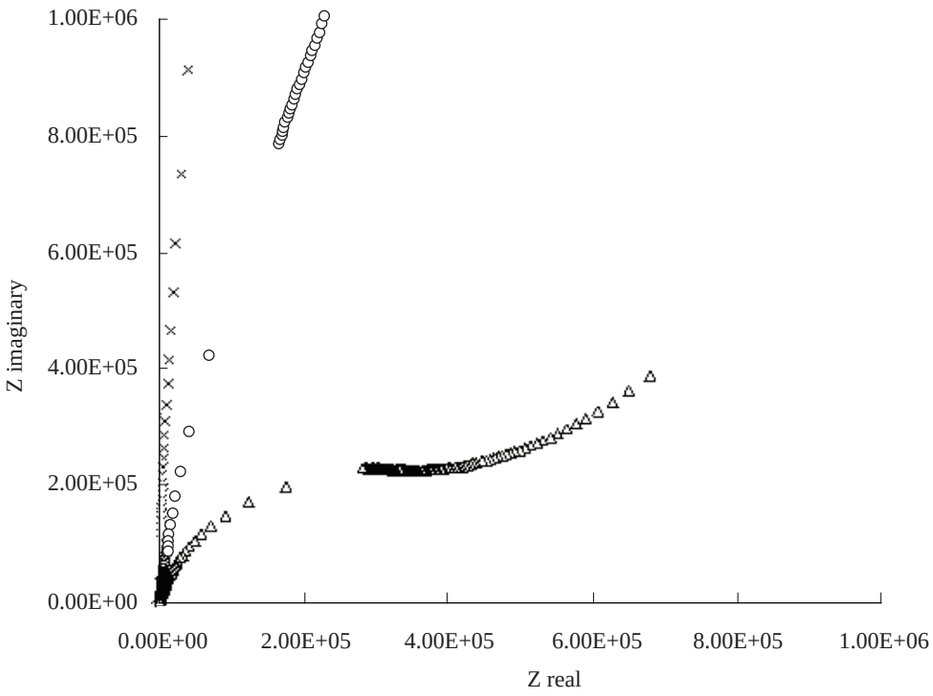

Figure 1. Impedance plots of pure PVC (x), PVC:$LiCF_3SO_3$ (85:15) (O) and PVC:$LiCF_3SO_3$ (75:25) (Δ).

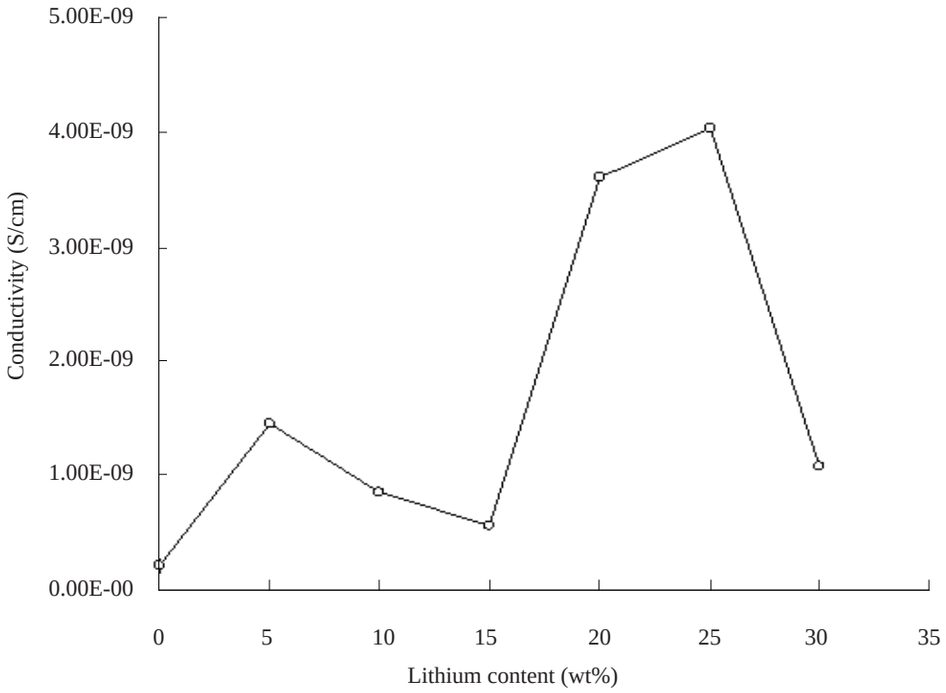

Figure 2. The conductivity plots of PVC:$LiCF_3SO_3$ for different lithium content.

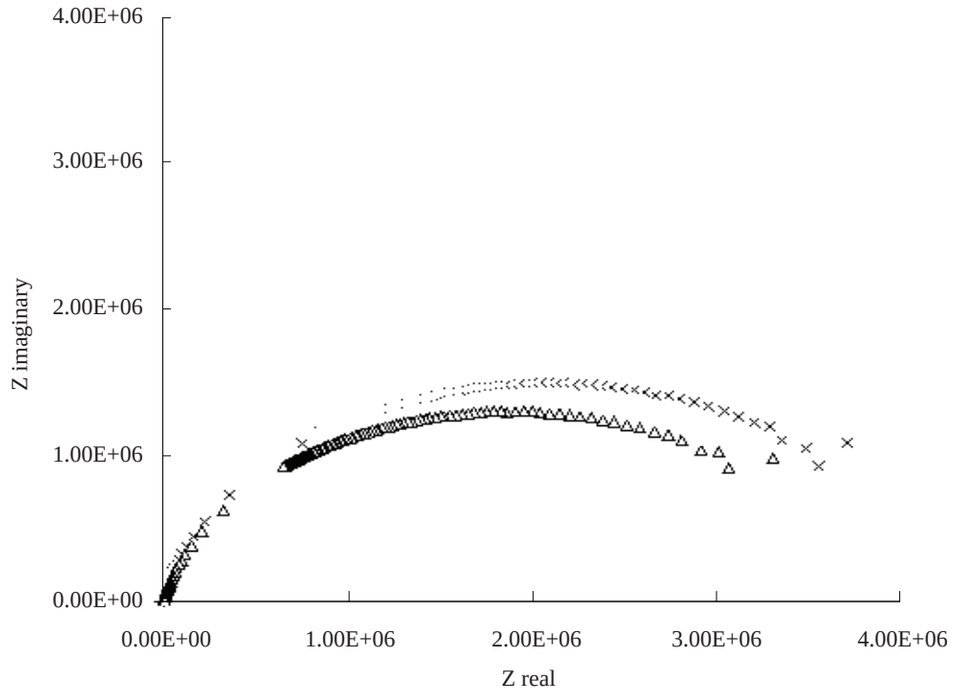

Figure 3. Impedance plots for PVC:$LiCF_3SO_3$ (70:30) at two different temperatures, 343 K (x) and 363 K (Δ).

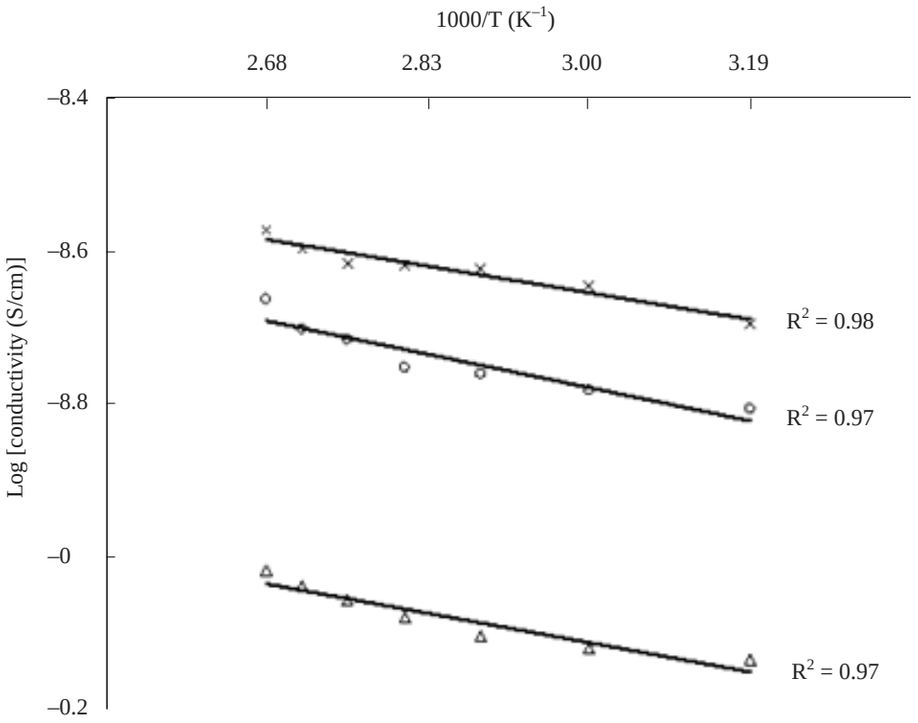

Figure 4. The temperature plot of log conductivity versus 1000/T of PVC:$LiCF_3SO_3$ (80:20) (o), PVC:$LiCF_3SO_3$ (75:25) (x) and PVC:$LiCF_3SO_3$ (70:30) (Δ).

complexation. The IR spectrum of each prepared polymer electrolyte varied according to the composition of PVC and $LiCF_3SO_3$ in the film and it was able to show the occurrence of interactions between the materials used. The FTIR spectra were recorded in percentage transmittance mode.

Analysis of PVC and PVC:$LiCF_3SO_3$ FTIR Spectra

Figure 5 shows the FTIR spectrum for pure low molecular weight PVC. The vibrational bands and wavenumbers exhibited by PVC FTIR spectrum are 636 cm^{-1} (*cis* CH wagging), 834 cm^{-1} (C-Cl stretching), 958 cm^{-1} (*trans* CH wagging), 1256 cm^{-1} (CH_2 rocking), 1332 cm^{-1} (CH_2 deformation), and 2911 (C-H stretching) which have been stated in literature (Rajendran & Uma 2000a; Rajendran & Uma 2000b; Vien *et al.* 1991; Beltran & Marcilla 1997).

The FTIR spectra of pure PVC and PVC: $LiCF_3SO_3$ polymer electrolytes are shown in Figure 6. As observed in Figure 6, when the ratio of $LiCF_3SO_3$ salt to PVC increases from 10 wt.% to 30 wt.%, the band at 636 cm^{-1} (*cis* CH_2 wagging) in pure PVC broadens and the small peak next to 636 cm^{-1} changes into a small shoulder. The band that corresponds to CH_2 deformation at 1332 cm^{-1} in pure PVC disappears upon addition of $LiCF_3SO_3$ salt. This implies that there are formations of ion aggregation and co-ordination of bonds.

Figure 7 shows the continuous changes in the peak shape of the PVC: $LiCF_3SO_3$ spectra at wavenumber 1256 cm^{-1} (CH_2 rocking) in PVC which confirms the interaction between the polymer-salt complexes in the polymer electrolyte films. Based on the obtained spectra, it can be seen that as the percentage weight of $LiCF_3SO_3$ salt increases from 10 wt.% to 30 wt.%, the peak becomes broader and flatter. This shows that at higher concentrations of $LiCF_3SO_3$, the interaction and complexation between the salt and polymer increase. The intensity of the small peak at 1199 cm^{-1}, next to 1256 cm^{-1} in the PVC FTIR spectrum decreases with small shifts of peak.

Analysis of $LiCF_3SO_3$ and PVC:$LiCF_3SO_3$ FTIR Spectra

The vibrational bands and wavenumbers that are observed in the pure $LiCF_3SO_3$ FTIR spectrum are 1033 cm^{-1} (symmetric SO_3), 1182 cm^{-1} (asymmetric CF_3), 1266 cm^{-1} (asymmetric SO_3), and other characteristic peaks at 1638 cm^{-1}, and 3490 cm^{-1} as shown in Figure 8.

The changes in the vibrational modes of the atoms or molecules together with the shape and intensity of the peaks were possibly induced by the interactions in the PVC: $LiCF_3SO_3$ polymer electrolyte matrices. Figure 9 illustrates the FTIR spectra of pure $LiCF_3SO_3$ compared with PVC: $LiCF_3SO_3$. Based on Figure 9, the symmetric SO_3 band at 1033 cm^{-1} shifts to 1040, 1035, 1047, 1038, and 1039 cm^{-1} as the content of $LiCF_3SO_3$ in the polymer electrolyte film increases. A small shoulder which exists (after addition of $LiCF_3SO_3$ salt) beside the 1040 cm^{-1} peak in Figure 9 (a) at higher wavenumber becomes more obvious with higher additional $LiCF_3SO_3$ concentration.

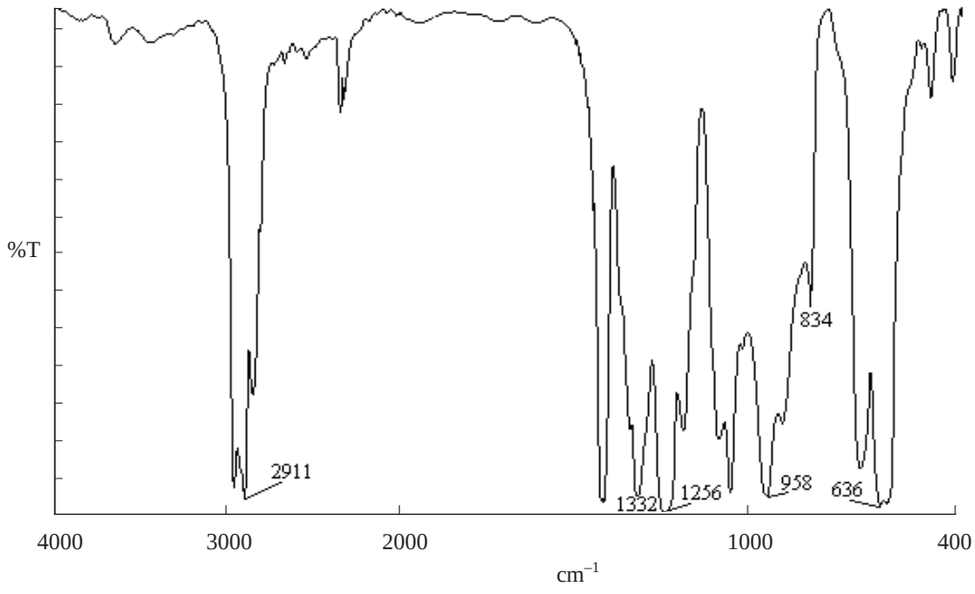

Figure 5. FTIR spectrum of pure PVC.

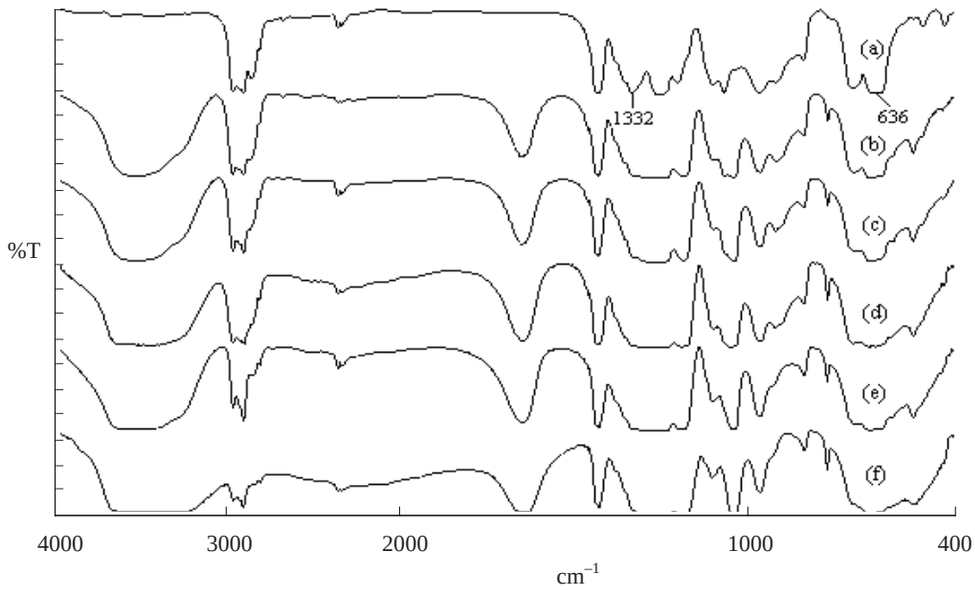

Figure 6. FTIR spectra for: (a) pure PVC; (b) PVC:$LiCF_3SO_3$ (90:10); (c) PVC:$LiCF_3SO_3$ (85:15); (d) PVC:$LiCF_3SO_3$ (80:20); (e) PVC:$LiCF_3SO_3$ (75:25); and (f) PVC:$LiCF_3SO_3$ (70:30).

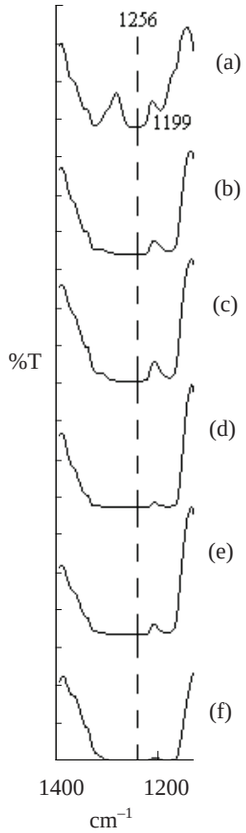

Figure 7. Changes to the CH-rocking vibration (1256 cm^{-1}) of PVC with the polymer electrolytes: ((a) pure PVC, (b) PVC:$LiCF_3SO_3$ (90:10); (c) PVC:$LiCF_3SO_3$ (85:15); (d) PVC:$LiCF_3SO_3$ (80:20); (e) PVC:$LiCF_3SO_3$ (75:25); and (f) PVC:$LiCF_3SO_3$ (70:30).

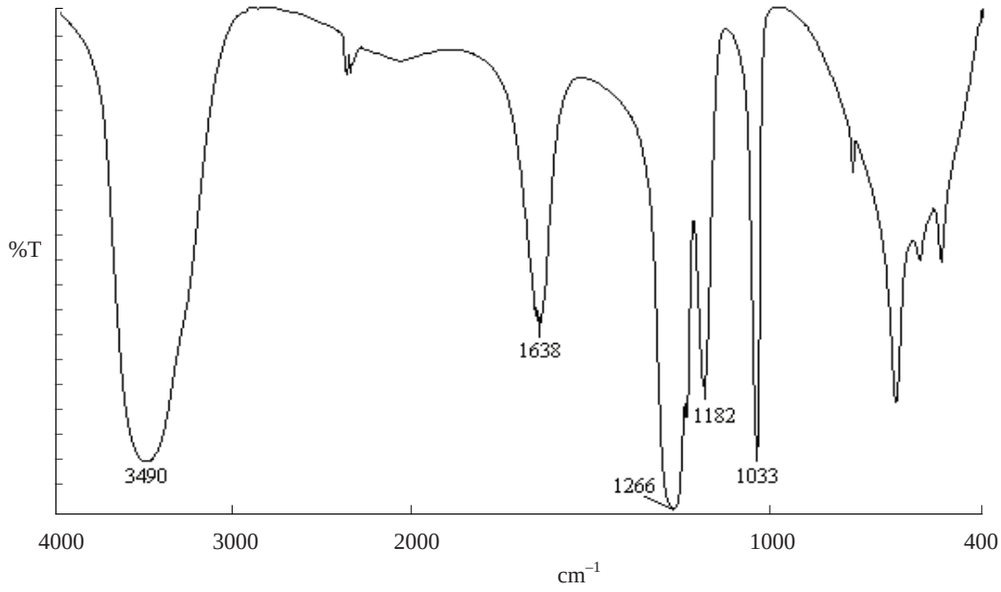

Figure 8. FTIR spectrum of pure $LiCF_3SO_3$.

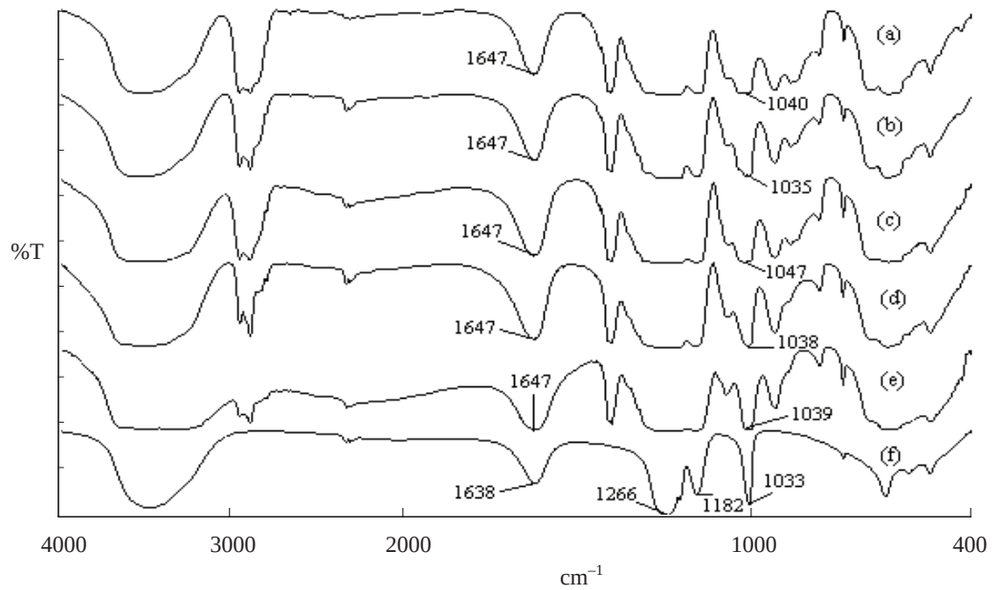

Figure 9. FTIR spectra for: (a) PVC:$LiCF_3SO_3$ (90:10); (b) PVC:$LiCF_3SO_3$ (85:15); (c) PVC:$LiCF_3SO_3$ (80:20); (d) PVC:$LiCF_3SO_3$ (75:25); (e) PVC:$LiCF_3SO_3$ (70:30) and (f) pure $LiCF_3SO_3$.

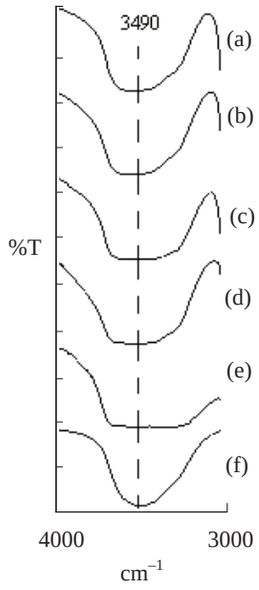

Figure 10. Changes to the bands existing in pure $LiCF_3SO_3$ (3490 cm^{-1}); (a) PVC:$LiCF_3SO_3$ (90:10); (b) PVC:$LiCF_3SO_3$ (85:15); (c) PVC:$LiCF_3SO_3$ (80:20); (d) PVC:$LiCF_3SO_3$ (75:25); (e) PVC:$LiCF_3SO_3$ (70:30); and (f) pure $LiCF_3SO_3$).

The intensity of peak at 1182 cm^{-1} decreases with a slight shift as the $LiCF_3SO_3$ salt increases. The peak at 1266 cm^{-1} becomes broader and flatter for the same condition. In addition, the peak at 1638 cm^{-1} for the pure $LiCF_3SO_3$ shifts to 1647 cm^{-1}. The broad peak at 3490 cm^{-1} continues to broaden as the percentage of $LiCF_3SO_3$ salt to PVC increases as revealed in Figure 10.

Herewith, it can be concluded that there are some changes in the environmental surroundings of the PVC and $LiCF_3SO_3$ atoms when more free mobile ions are present in the polymer-salt blends. The attributed changes contribute to the alternations in the cage peak as discussed earlier.

CONCLUSION

In these conductivity studies, it could be viewed that the conductivity values were directly proportional to the salt concentration in polymer electrolyte films but only up to a certain composition, after which the conductivity value decreased. In this study, the highest conductivity value was obtained for PVC: $LiCF_3SO_3$ polymer electrolytes with a composition ratio of 75:25 with a calculated conductivity value of 4.04×10^{-9} S cm^{-1}. On the other hand, the FTIR studies that were carried out have proved that interactions occured between the PVC: $LiCF_3SO_3$ blends, which were evident by the shifting of peaks and changes in both the shape and intensity of peaks.

Date of submission: May 2011
Date of acceptance: July 2011

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ASM Sci. J., **5(1)**, 27–35

Mechanical Properties of Wood-wool Cement Composite Board Manufactured Using Selected Malaysian Fast Grown Timber Species

Z. Ahmad[1], L.S. Wee[1]* and M.A. Fauzi[1]

This paper reports the mechanical properties of cement composite boards made using wood-wool from a lesser known Malaysian timber species. A total of 108 specimens were fabricated using Portland cement (Type I) and wood-wool from Kelampayan (*Neolamarckia cadamba*). The cement to wood ratio of the specimens was 2 to 1 by weight. The aim of the study was to determine the density; flexural, compressive and tensile strength of wood-wool cement composite boards (WWCCB) by studying boards with wood-wool sized 1.5 mm, 2.5 mm and 3.5 mm and board thickness 25 mm, 50 mm and 75mm. The physical and mechanical properties of the boards were evaluated according to ASTM D 1037-96a (Standard testing method for evaluating properties of wood-based fibre and particle panel materials) and MS934:1986. Results showed that mechanical properties of WWCCB were greatly influenced by the density; as the density decreased, the mechanical strengths also decreased. However, the strength properties of the composite boards did not display a similar trend when subjected to different types of loading conditions. The compressive strength increased with thicker boards (50 mm and 75 mm) but the modulus of elasticity and modulus of rupture declined as the thickness of the board was increased.

Key words: wood-cement composite; compressive strength; tensile strength; flexural strength; strength properties; modulus; elasticity; rupture; loading conditions; Kelampayan (*Neolamarckia cadamba*); thickness

A wood-cement particle composite is composed of wood material, cement and water. This composite product is generally produced in two groups, cement particleboard and cement wood-wool board. Cement particleboard has high density and a smooth surface while wood-wool cement board is low in density and has a porous surface. Cement particleboard because at its bigger surface area has been used in the construction of low-cost housing which requires less cement mortar and man-hours during construction as compared to brickwork. However, the weight of cement particle board has become an issue during construction and it also poses a significant factor in the design which results in a rise in the construction cost. The addition of wood particles in the production of cement-bonded particle board in fact increases the mechanical properties and improves the toughness of the board but unfortunately this does not solve the problem of the ratio of high weight to strength. Wood-wool cement composite board (WWCCB) comprises wood-wool and cement where the wood-wool is produced by shredding logs using a special shredding machine. Since wood-wool is light and has a high aspect ratio, the wood-wool cement composite board is lighter than the cement particleboard.

WWCCB has outstanding potential as a housing and building component because it resists biological degradation and has excellent heat and noise insulation capabilities. Studies have been conducted on various parameters for the production of WWCCB such as wood species, wood-cement ratio, type of particle accelerator, amount of water, soaking time and board density (Van Elten 2006; Hachmi & Moslemi 1989; Hachmi & Sesbou 1991). The studies were concentrated on locally available wood species and this has led to the establishment of several WWCCB used mainly indigenous species (Pablo 1989). The bonding strength between wood and cement depends primarily on the wood species selected (Lee & Hong 1986). Badejo (1988) studied two variables (flake length and thickness) of wood-cement panels using flake from three types of tropical hardwoods, and his results showed that these two variables were highly correlated with modulus of elasticity (MOE), modulus of rapture (MOR), water absorption and thickness of swelling. The longer and thinner the flakes, the stronger, stiffer and more dimensionally stable were the boards.

The most important limitation for the manufacturing of inorganic-bonded wood composite boards is the highly variable compatibility between wood and the inorganic binder. It has been found that organic materials inhibit the setting of cement and reduce cement strength. Several factors can affect this compatibility. For instance, the chemistry and amount of wood-water soluble extractives

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strongly influence compatibility (Del Menezzi *et al.* 2007; Papadopoulos 2009). Species containing more than 7% of hot water soluble extractives could be considered as incompatible (Noor Azrieda *et al.* 2009). Extractive compounds can delay the hydration of inorganic binders, affecting the morphology and size of the hydrate crystals. As a consequence, they can affect the adhesion of inorganic binders to wood (Simatupang *et al*. 1989; Zhou and Kamden 2002; Papadopoulos *et al*. 2006). In order to reduce this incompatibility, hot water extractions of wood were proposed (Sutigno 2002; Okino *et al*. 2003). For this study, the wood-wool was rinsed with water to remove the extractives.

The aim of this study is to produce board with a density target of 300 kg/m^3 to 500 kg/m^3 (considered low density board) in order to take advantage the light weight but to maintain high strength in order for it to be used as a non-load bearing structural element.

As the performance of the wood-wool cement composite depends on the choice of timber species used, this study therefore explores the potential of using wood-wool from a Malaysian fast grown timber species namely Kelampayan (*Neolamarckia cadamba*) for the manufacture of WWCCB. Flexural, compressive and tensile strengths of WWWCB were examined in this study and the variables were the wood-wool size and board thickness.

MATERIALS AND METHOD

Raw Materials

The wood wool used in this study was shredded from 4–5 year-old Kelampayan (Neolamarckia cadamba) which is in the category of fast grown timbers. The logs were cut into billets, 35 cm – 40 cm long, debarked and made into wood-wool of width sizes 1.5 mm, 2.5 mm and 3.5 mm (Figure 1) using a vertical-type shredding machine.

Wood-wools was soaked in water at room temperature for 24 h. This was done to remove sugar and excessive extractives from the wood. Once treated, the wood-wool was air-dried until the moisture content of wood-wool was about 12%. Ordinary Portland Cement (OPC) was used as the binder.

Preparation of Wood-wool Board

Wood-wool, cement and water in the ratio of 2:1:1(respectively by weight), were mixed by hand until all the wood-wool was thoroughly coated with cement paste. Sufficient cement-coated wood-wool was spread out in the wooden forming box moulds (600 mm × 2400 mm) at different thickness (25 mm, 50 mm and 75 mm). Prior to that, a layer of grease was applied onto the mould for ease of demoulding. A layer of polymer mat was placed on top of the cement mixture to prevent the board from sticking during compression. The board was can pressed using heavy concrete blocks for 5–7 days. After being demoulded, the boards were air-dried for further curing for up to 28 days. A total of 18 boards were fabricated with wood-wool size of 1.5 mm, 2.5 mm and 3.5 mm for 25 mm, 50 mm and 75 mm thickness of boards.

Test Specimens for Mechanical Properties

A total of 108 specimens were prepared at random from the fabricated wood-wool boards according to the requirement of the test as shown in Table 1.

TEST METHODS

Density

The specimens for density determination were taken by cutting the specimens from different parts of the board in accordance with Malaysian Standard: MS934:1986

Figure 1. Wood-wools of different sizes.

Table 1. Dimensions of test specimens.

No	Type of test	Thickness of board (mm) 25	50	75	Total specimens
		Dimension, width (B) x length (L) (mm)			
1	Density	100 × 100	100 × 100	100 × 100	27
2	Flexural strength (MOR) & Modulus of elasticity (MOE)	100 × 425	100 × 825	100 × 1225	27
3	Tensile test or internal bond test (IB)	40 × 40	40 × 40	40 × 40	27
4	Compression test	25 × 100	50 × 200	75 × 300	27

Compression Test

The compression test was carried out according to the short column procedure (*Procedure C*) in ASTM D1037-99 using a UTM1000 machine at a loading rate of 1.5 mm/min as shown in Figure 2. The specimens were tested with a load parallel to the board thickness.

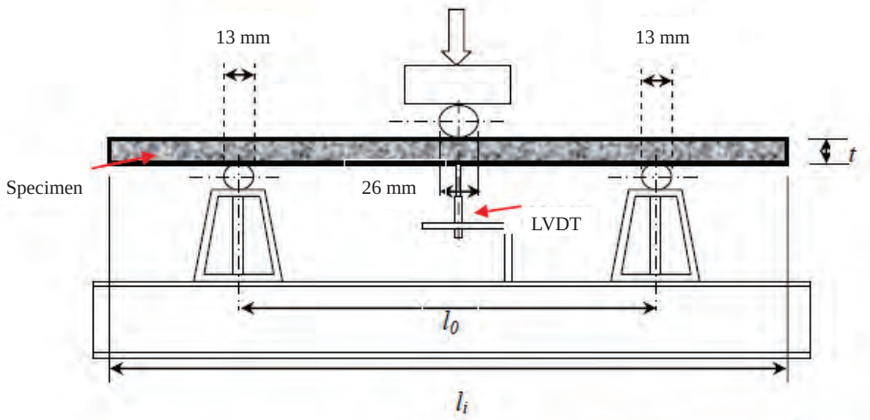
Bending Test

The bending strength was measured by the three-point loading test which was carried out in accordance with Malaysian Standard: MS934:1986 as shown in Figure 3. The span length was 16 times the thickness of the board. The displacement at the centre of the span and the corresponding loads were recorded. Load was applied in the flat direction and edge-wise at the rate of 0.5 mm/min.

Tensile Test

The tensile test or internal bond test was conducted according to ASTM D1037. The specimen size was 40 mm × 40 mm × thickness of boards (25 mm, 50 mm, and 75 mm). Epoxy 2-ton® was used for bonding the cement board and the metal plate. Figure 4 shows the test set up for the internal bond test.

Figure 2. Compression test set-up.



Where,

F = Load cell

t = Thickness of specimen

$l_0 = 16t$

$l_i = 16t + 50$

Figure 3. Bending test set-up; showing schematic diagram and actual test set up.

Where,

1 = Metal block

2 = Specimen

3 = Glue (epoxy)

F = Load

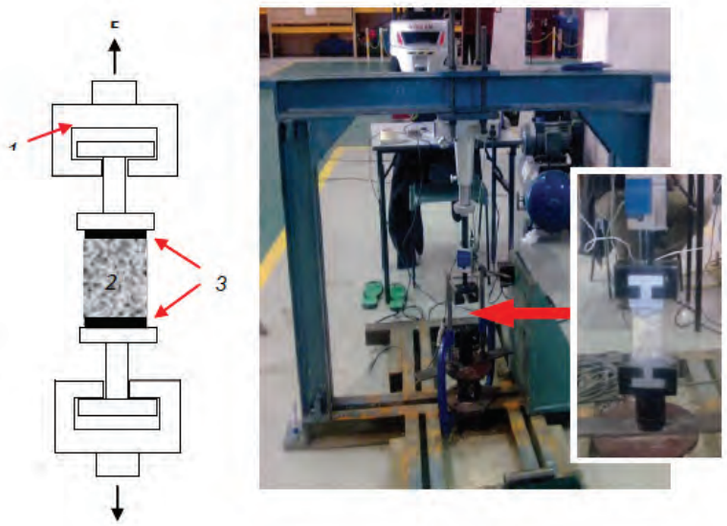


Figure 4. Tensile test set up.

RESULTS AND DISCUSSION

Mechanical Properties

The mechanical properties (density, flexural strength, compression strength and tensile strength) of WWCCB are summarized in Table 2. The results presented are the average of 5 specimens for each configuration of the test. The results showed that the mechanical strength of WWCCB was greatly influenced by the density of the board. The density decreased with the increase of the wood-wool size. The strength also decreased with decrease in density decreases. Thus density is the best predictor of the timber composite strength (Dinwoodie 2001). The mean density of boards with 1.5 mm wood-wool was the highest for each thickness of WWCCB (0.74 g/cm^3, 0.44 g/cm^3, and 0.47 g/cm^3 respectively). This revealed that the smaller size of the wood-wool makes the board denser and easy to compact.

The strength of the WWCCB was not only affected by the density of the board but also the density of the wood. Boards made from Gmelina arborea, a low-density wood species (density is 480 kg/m^3), had a higher MOR (ranging from 8.74 N/mm^2 to 16.54 N/mm^2) when compared with boards from high-density wood, Leucaena Leucocephala (density is 690 kg/m^3) with MOR ranging from 5.94 N/mm^2 to 10.79 N/mm^2 (Babatunde 2008). These values are higher than the MOR values from the present studies since the wood-wool used were treated to improve the bonding between the cement and the wood-wool. Again, the strength of the board could be improved using lower density wood species and proper treatment.

Figures 5 to 7 show the typical load-displacement curves from the flexural test for 25 mm, 50 mm and 75 mm thickness of WWCCB with different sizes of wood-wool. The load-displacement curves obtained display significant non-linearity and indicate that the wood-wool cement composite was ductile and had the capability to absorb energy which can be observed from the area under the graph.

In general, the WWCCB with 1.5 mm wood wool sizes was much stiffer than other wood wool sizes for all thicknesses of the boards. For the three thickness series of board, the highest load carrying capacity in flexure was obtained for WWCCB with 1.5 mm wood-wool.

This was followed by the WWCCB with 2.5 mm and 3.5 mm wood-wool, in descending order. The corresponding deflection at maximum load for 3.5 mm was ranked as the highest among the three sizes of wood-wood.

The smallest size of wood-wool (1.5 mm) and the least thick board (25 mm) significantly contributed to the flexural strength (the value of MOR) of the WWCCB as shown in Figure 8. It could be seen that the flexural strength decreased with the increase of the wood-wool size and the board thickness. The values of MOR ranged from 0.77 MPa to 1.2 MPa for WWCB with 1.5 mm thick wood wool. However, the MOE remained stable within 0.12 GPa – 0.16 GPa for the 1.5 mm and 2.5 mm wood-wool sizes at the three different thicknesses of the boards. It is well-known that cement is stiffer than wood, so with the same ratio of cement to wood-wool, the smaller sized wood-wool would be able to be coated easily by the cement, hence producing better bonding and higher strength value. Moslemi and Pfister (1987) argued that when wood occupies more volume in a board due to the smaller sizes of wood-wool, the regions of stress concentration around the adjacent particles are diffused, resulting in an increase in the applied stress. German DIN 1101 compiled physical and mechanical properties of WWCB for low density board (250 kg/m^3 to 600 kg/m^3). The values ranged from 0.4 MPa to 1.7 MPa for MOR. The values found in the present study were within this range for MOR except for 75 mm board

Table 2. Summary of mechanical properties for WWCCB.

Thickness of WWCCB (mm)	No. of samples	Wood-wool sizes (mm)	Density (ρ) (g/cm3)		Flexural properties				Compressive strength (MPa)		Tensile strength (MPa)	
			Mean	SD	MOE (GPa)	SD	MOR (MPa)	SD	Mean	SD	Mean	SD
25	5	1.5	0.74	0.10	0.16	0.03	1.22	0.68	0.11	0.01	0.09	0.02
	5	2.5	0.49	0.03	0.15	0.01	1.05	0.27	0.08	0.01	0.06	0.00
	5	3.5	0.28	0.03	0.05	0.01	0.55	0.24	0.06	0.00	0.06	0.00
50	5	1.5	0.44	0.06	0.15	0.01	0.77	0.01	0.08	0.00	0.07	0.00
	5	2.5	0.42	0.02	0.14	0.00	0.68	0.03	0.06	0.02	0.03	0.00
	5	3.5	0.39	0.01	0.14	0.00	0.62	0.01	0.03	0.01	0.01	0.00
75	5	1.5	0.47	0.02	0.16	0.03	0.77	0.03	0.08	0.01	0.03	0.00
	5	2.5	0.45	0.02	0.12	0.00	0.51	0.02	0.04	0.00	0.03	0.01
	5	3.5	0.44	0.02	0.07	0.01	0.23	0.04	0.02	0.00	0.004	0.00

with 3.5 mm wood-wool size. The values of compressive strength for thicker boards (50 mm and 75 mm) for the same series of wood-wool sizes were lower than the 25 mm thick board. These values were also found to be lower than the values specified in the German DIN 1101.

Forest Products Laboratory (1999) compiled physical and mechanical properties of several kinds of low density wood-cement board (WCB) (500 kg/m^3 to 1000 kg/m^3). The values ranged from 1.7 MPa to 5.5 MPa for MOR and from 0.62 GPa to 1.24 GPa for MOE. In comparison with those studies, the properties of boards manufactured here were different since the densities of the boards were higher.

The IB values of the boards showed the same trend as other properties. As the wood-wool sizes increased the IB values decreased for all thickness, ranging from 0.004 MPa to 0.09 MPa.

This property evaluates the tension strength perpendicular to the board surface, in other words, the bonding quality of the matrix formed by the wood and cement. The possible causes of such low IB values of larger wood-wool sizes could be due to the low cement to wood and wood to water ratio. As the wood-wool sizes were larger, the cement was unable to encapsulate them properly and this contributed to the poor which was reflected in the flexural and compression strength values. In commonly manufactured wood particle cement board, the cement:wood ratio was higher (4:1 or 3:1) than those used here (2:1). The IB strength was provided mainly by the cement matrix. These findings suggest that more research was needed to overcome the low IB values since it is an important property and the low values severely limited the application of wood-wool boards.

Modes of Failure

Figure 9 shows the example of failure modes from the tests conducted on the mechanical properties of the WWCCB.

Figure 9a shows the general pattern of the failure mode of compression specimens loaded parallel to the thickness of the board direction with a column aspect ratio (depth to breath ratio) of 4.

For all samples of 25 mm to 50 mm thickness, the compression failure typically occurred along the diagonal bands similar to the compression failure of concrete columns. However, for the 75 mm thick samples, there were cracks in the diagonal bands but without large openings.

The failure modes for tension and bending tests (Figure 9b and 9c, respectively) showed that the specimen failed around the centre.

CONCLUSION

The results of this experimental study showed that the mechanical properties of WWCCB were greatly influenced by the size of wood-wool and thickness of the board. The following conclusions could be drawn:

i. The WWCCB with 1.5 mm wood-wool size provided the highest values for flexural strength and elasticity

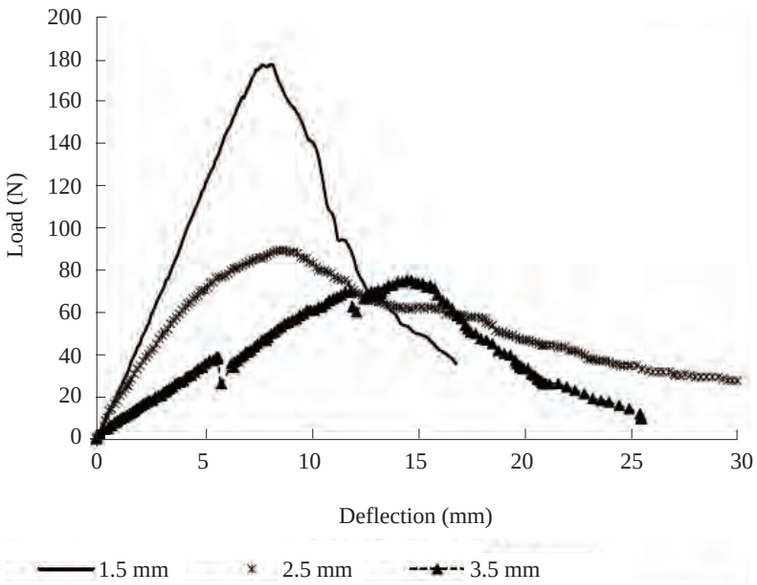


Figure 5. Typical load-displacement graph for flexural test (25 mm thick WWCCB).

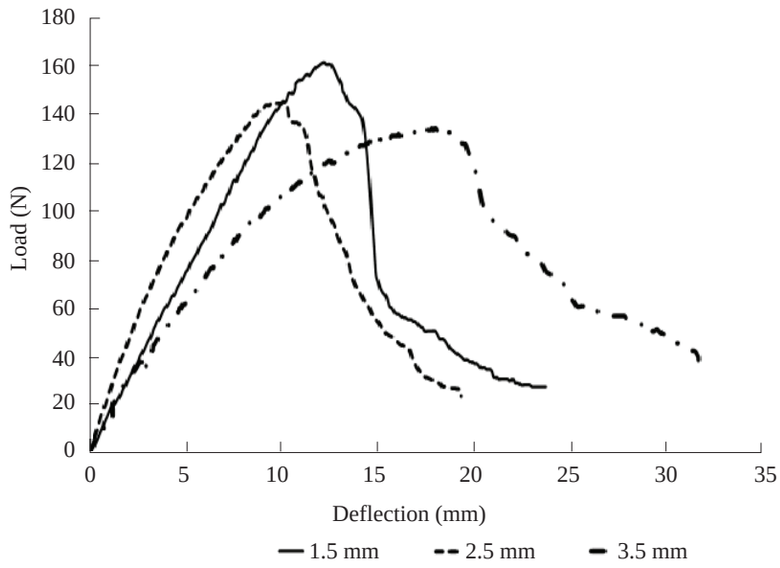


Figure 6. Typical load-displacement graph for flexural test (50 mm thick WWCCB).

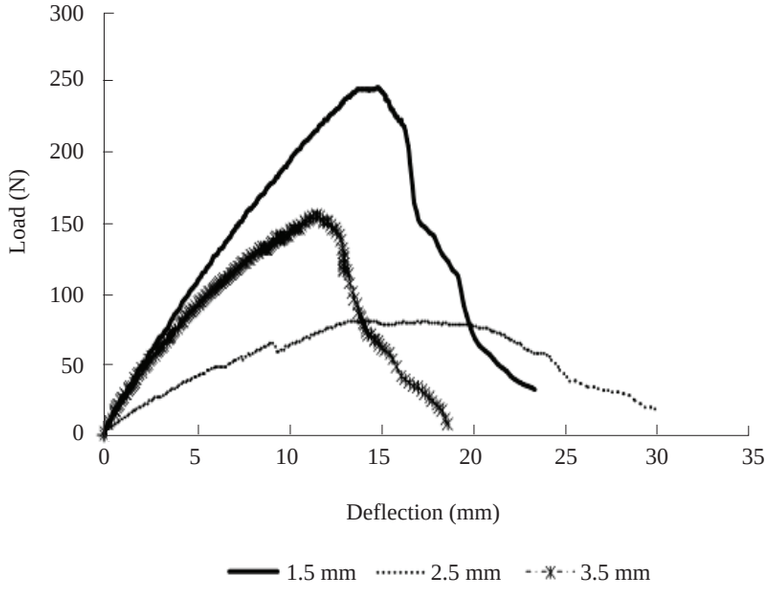


Figure 7. Typical load-displacement graph for flexural test (75 mm thick WWCCB).

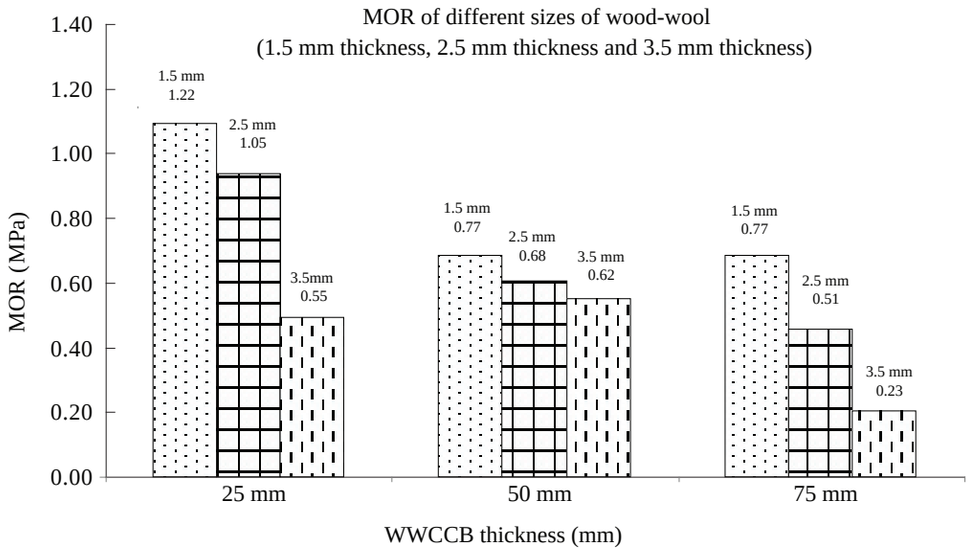
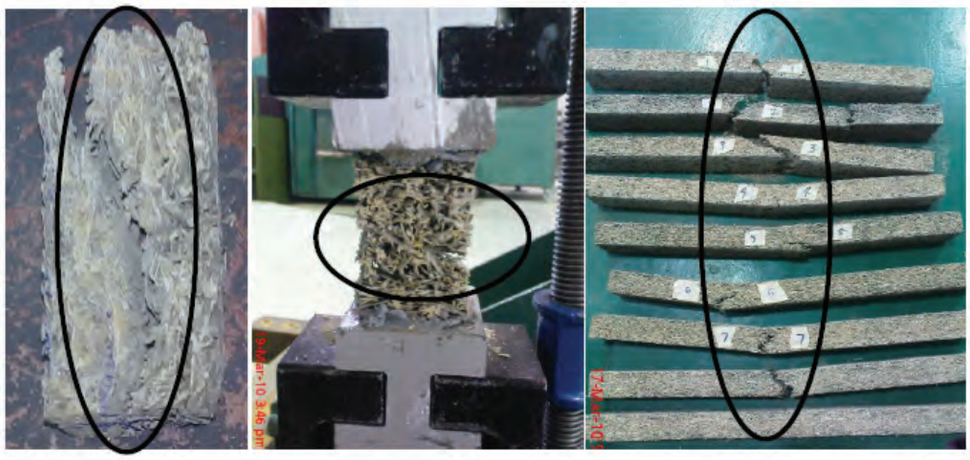


Figure 8. MOR values for different series of WWCCB.



(a) (b) (c)

Figure 9. Typical failure modes of specimens under (a) compression, (b) tensile and (c) bending compression. The position of crack is shown by the circle.

(MOR and MOE), compression strength, tensile strength and density as compared to WWCCB with 2.5 mm and 3.5 mm wood-wool sizes.

ii. In term of thickness of the WWCCB, 25 mm was an ideal thickness to yield the optimum value of flexural strength (MOR), compressive strength, tensile strength, density as compared to 50 mm and 75 mm. Moreover, the thin boards performed better than the thicker boards.

iii. Boards produced at the highest levels of board density were the strongest.

iv. The low density board cement bonded wood-wool boards (250 kg/m^3 to 600 kg/m^3) produced in this study met the modulus of rupture and modulus of elasticity requirements in accordance with German DIN 110 when thinner wood-wool sizes were used. The values ranged from 0.4 MPa to 1.7 MPa for MOR.

ACKNOWLEDGEMENTS

The provision of wood wool by Duralite (M) Sdn Bhd is gratefully acknowledged. We wish to thank the technicians of the Civil Engineering Faculty and the Faculty of Mechanical Engineering, Universiti Teknologi MARA for their assistance and support.

The work reported here was financially supported by the the Institute of Research, Development and Comercialization, Universiti Teknologi Mara, Malaysia.

Date of submission: January 2011
Date of acceptance: September 2011

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ASM Sci. J., **5(1)**, 36–42

Short Communication
Physical Characterization of the Screen-printed Carbon Electrode Surface Using Scanning Electron Micrograph

R. Issa[1]*, N.A. Hamdan[1], A.S.S. Raj[2] and M.F.M. Noh[3]

Researchers have developed and modified DNA biosensor techniques to provide a fast, simple and sensitive method for detection of human diseases, bacterial food contamination, forensic and environmental research. This study describes the physical characterization of screen-printed carbon electrodes using the scanning electron microscope.

Key words: DNA biosensor; detection; human diseases; DNA sequences; *mycobacterium tuberculosis*; differential pulse voltammetry; electrochemical technique; covalent attachment

The DNA biosensor technique using screen-printed carbon electrodes (SPCE) can be used for the detection of DNA sequences related to the *Mycobacterium tuberculosis* (TB). Differential pulse voltammetry (DPV) measurements of electrochemical technique were carried out to investigate the voltammetric responses of SPCE. The purpose of the study was to physically characterize the SPCE using scanning electron micrograph (SEM). The characterization of SPCE was based on the covalent and non-covalent attachment.

Two types of substrates are commonly used in screen-printing, ceramic and plastic-based materials (Grennan *et al*. 2008). The electrodes used in this study were based on polycarbonate. The SPCE was fabricated by a local company ScrintTechnology Sdn Bhd, located in Sungai Petani, Malaysia. The SPCE consisted of three electrodes system including counter, working and reference electrodes (also known as silver pseudo reference electrodes). The SEM of the SPCE surface is shown at different magnifications of $\times$3131 and $\times$11 524 (Figure 1).

For the analysis of the non-covalent attachment (Issa *et al*. 2010), the SPCE surface was activated using 0.5 M of acetate buffer solution (ABS, pH 4.8). A potential of 1.4 V was applied for 60 s and then washed with sterile distilled water for 5 s. Then, 10 µg/ml of MYC TB Probe was immobilized onto the activated SPCE surface for 25 min. The surface was then washed with ABS for 5 s and the electrode surface was dried. About 20 µl of 15 µg/ml MYC TB Target was hybridized onto the electrode surface for 6 min and then washed with 0.02 M of Tris-HCl containing 20 mM of NaCl (pH 7.0). The procedure was repeated three times (n = 3) to obtain the condition of the electrode surface at three different steps: activation, immobilization and hybridization for the SEM characterization.

Meanwhile, for the analysis of covalent attachment, the activation of electrode surface was done by immobilizing the surface with a specific coupling agent *N*-hydroxysuccinimide-N-(3-dimethylaminopropyl)-N'-ethyl-carbodiimidehydrochloride (NHS-EDC) for 10 min. The electrode was washed with sterile ultrapure water for 5 s. The procedures for immobilization of modified MYC TB Probe and hybridization with MYC TB Target were similar to the non-covalent attachment (Issa *et al*. 2010).

Figure 2 shows the SEM of a SPCE surface at room temperatures of 24ºC–28ºC. The scanning images were done for non-covalent attachments, with the activated SPCE surface pretreated with ABS (pH 4.8). Figure 2 (i) displays the image of pretreated SPCE surface using 0.5 M of ABS (pH 4.8) after a conditioning time of 60 s. Meanwhile, Figure 2 (ii) shows the image of a pretreated-

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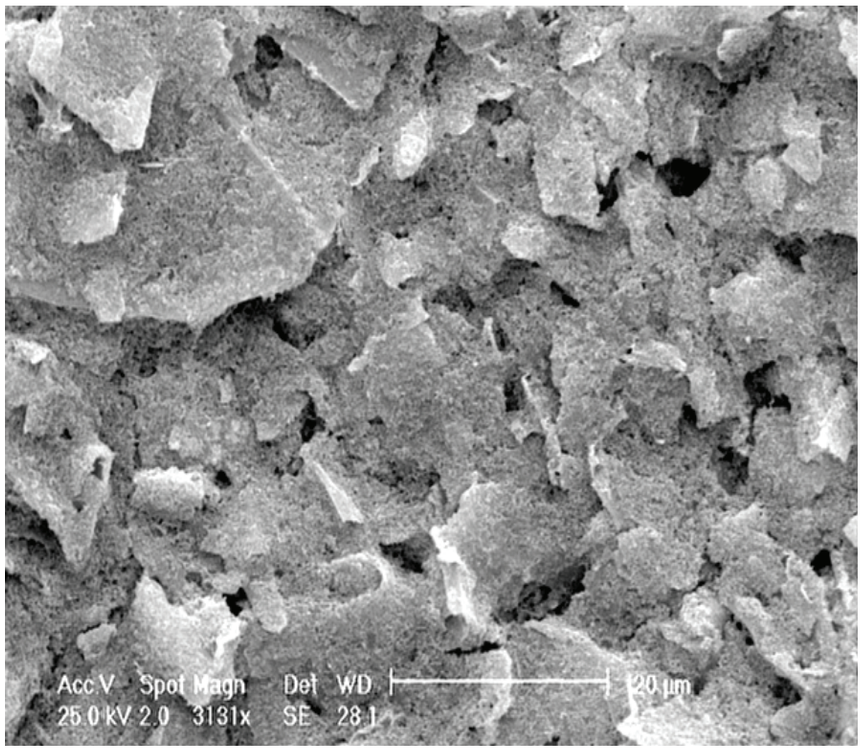
(a)



(b)

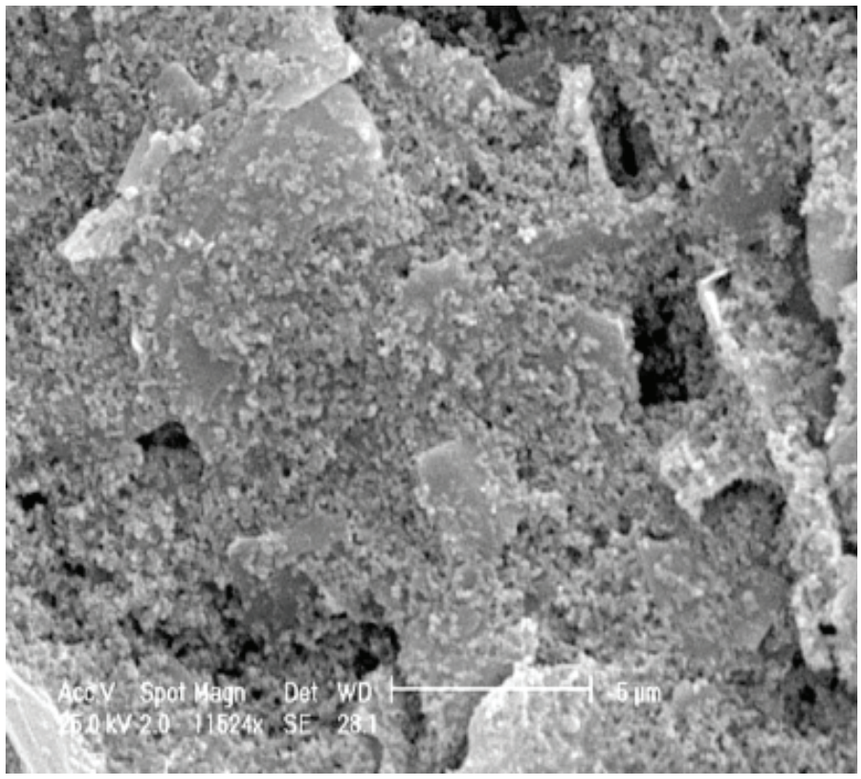


Figure 1. Screen-printed carbon electrode (SPCE) at magnification (a) ×3131 and (b) ×11 524.

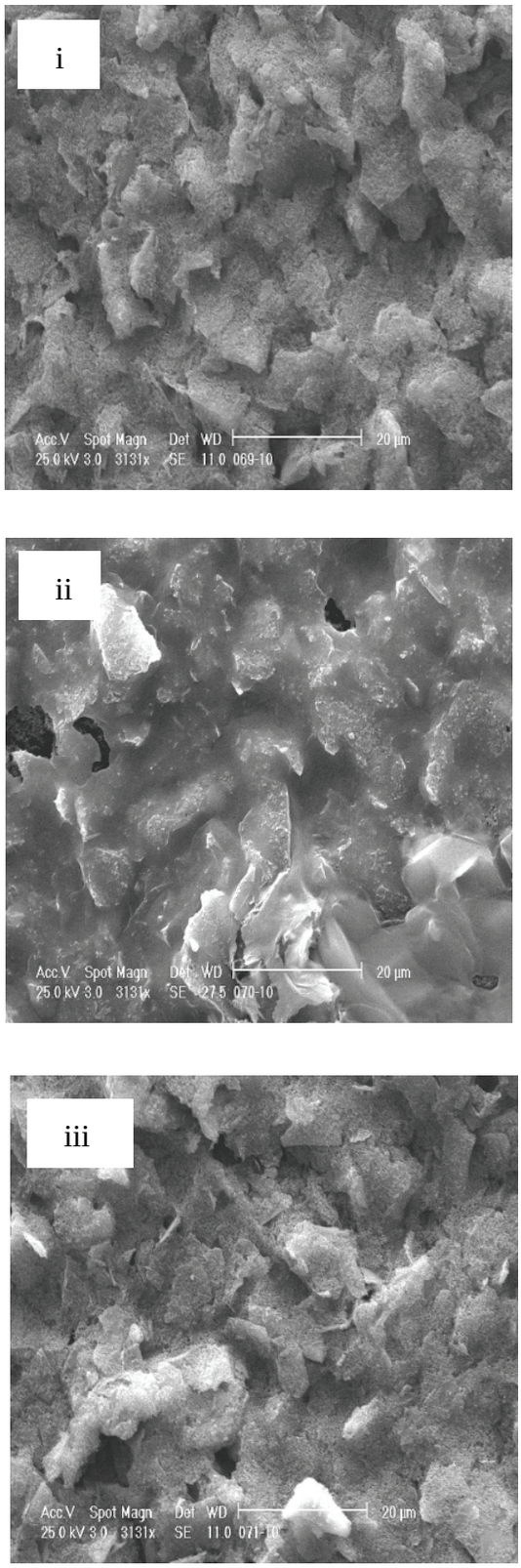
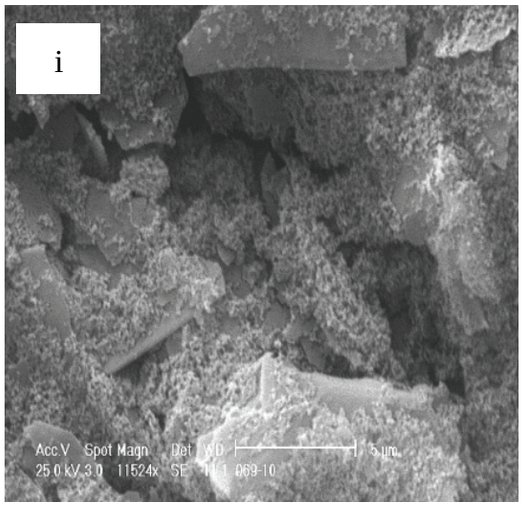
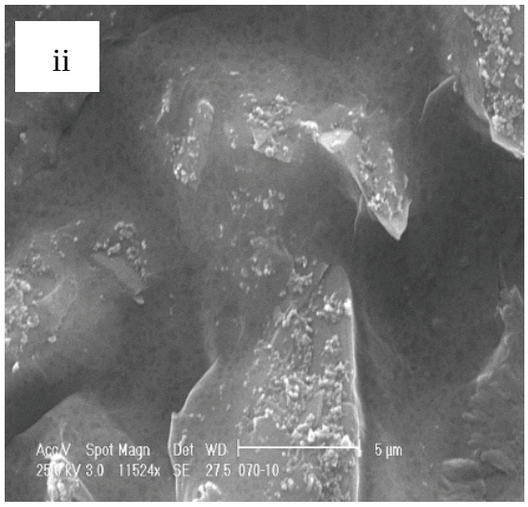


Figure 2. Analysis of electrode surface for non-covalent attachment. SPCE after pretreatment with: (i) 0.5 M of ABS (pH 4.8); (ii) after immobilization with MYC TB Probe, and (iii) after hybridization with MYC TB Target. SEM of the carbon reactive surface of SPCE (×3131 magnification) at room temperature.





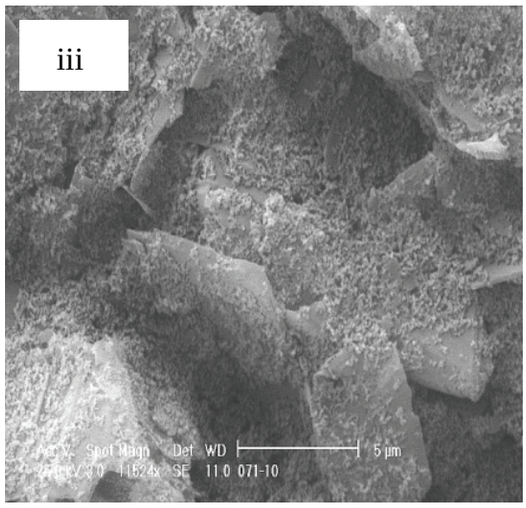


Figure 2 (cont.). Analysis of electrode surface for non-covalent attachment. SPCE after pretreatment with: (i) 0.5 M of ABS (pH 4.8); (ii) after immobilization with MYC TB Probe, and (iii) after hybridization with MYC TB Target. SEM of the carbon reactive surface of SPCE (×11 524 magnification) at room temperature.

SPCE surface after immobilized with MYC TB Probe, followed by hybridization process with MYC TB Target [Figure 2 (iii)].

As can be seen in Figures 1 and 2, the roughness of the surface of the carbon particles increased dramatically as compared to the electrode without pretreatment process. As observed by Wang *et al*. (1996), electrode pre-activation might have improved the electron transfer kinetics at the electrode surface which would otherwise have been retarded due to the inherent make up of the electrode at the high oxidation potentials of +1.5 to +2.0 V. When the electrode undergoes pretreatment process, a greater degree of cracking is induced on the surface of the carbon electrode, which increases the effectiveness of the surface area of the working electrode for DNA attachment during immobilization and hybridization processes. This condition gives an advantage for the MYC TB Probe to bind onto the modified-SPCE surface. Furthermore, the condition also facilitates the hybridization process which occurs between MYC TB Probe and MYC TB Target.

Figure 3 illustrates the SPCE surface for covalent attachment. Electrodes that had undergone pretreatment process with NHS-EDC for 10 min showed similar observations as for non-covalent attachment. From the SEM it could be seen that the electrode surfaces for covalent attachments after immobilization with MYC TB Probe and hybridization with MYC TB Target were similar to the electrode surfaces of non-covalent attachments. DPV measurements through electrochemical analysis were carried out to investigate the voltammetric responses of SPCE via non-covalent attachments (Issa *et al.* 2010). The results obtained from the measurements

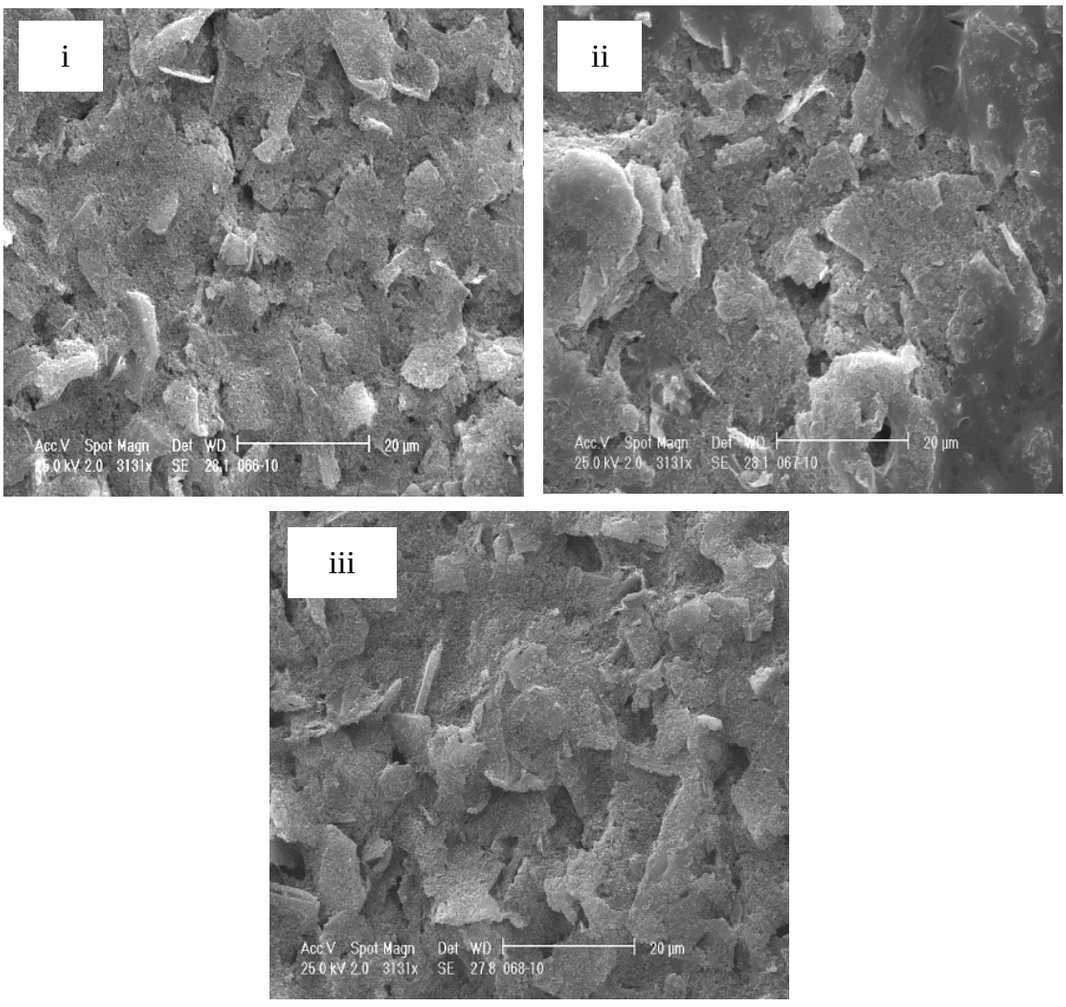


Figure 3. Analysis of electrode surface for covalent attachment. SPCE after pretreatment with: (i) NHS-EDC for 10 min; (ii) after immobilization with MYC TB Probe, and (iii) after hybridization with MYC TB Target. SEM of the carbon reactive surface of SPCE (×3131 magnification) at room temperature.

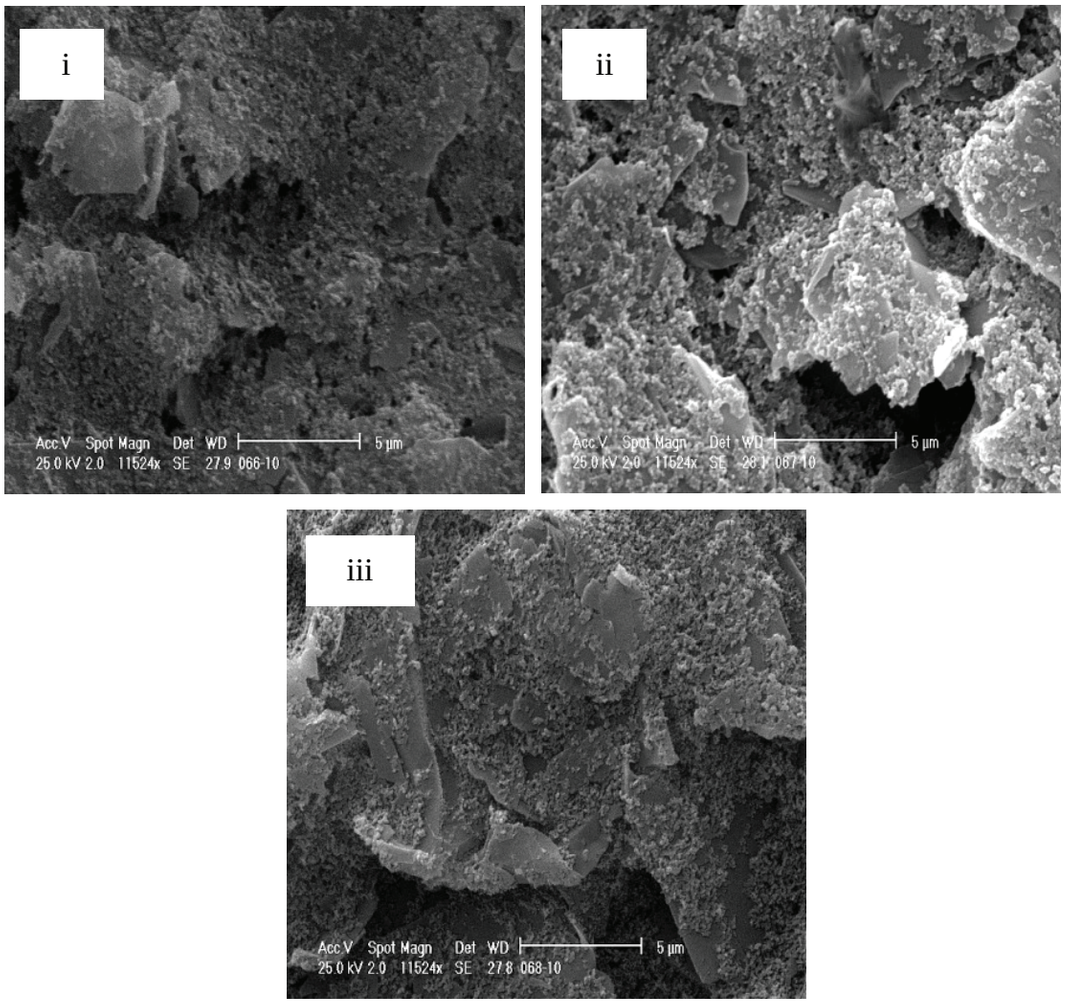


Figure 3 (cont.). Analysis of electrode surface for covalent attachment. SPCE after pretreatment with: (i) NHS-EDC for 10 min; (ii) after immobilization with MYC TB Probe, and (iii) after hybridization with MYC TB Target. SEM of the carbon reactive surface of SPCE (×11 524 magnification) at room temperature.

(not shown here) indicate that the DPV signals of covalent attachments were higher as compared to the non-covalent attachments. NHS-EDC provides functional groups for the covalent attachment of the DNA probe. EDC is used to activate carboxyl groups and NHS stabilizes the active amine-reactive intermediate. Erdem *et al.* (2000) reported that the reagents of carbodiimide and *N*-hydroxysuccinimide allowed DNA to associate to the stearic acid-modified SPCE through deoxyguanosine residues for the adsorption of DNA oligonucleotides containing guanine bases.

CONCLUSION

The physical characterization of SPCE surfaces via covalent and non-covalent attachment analysis had been explored using SEM. The electrode surfaces of covalent attachments were similar with the non-covalent attachments. However, it could still be differentiated by DPV measurements as covalent attachment allowed the absorption of DNA oligonucleotides (Erdem *et al*. 2000).

ACKNOWLEGDEMENTS

This study was funded by Ministry of Health (MOH), Malaysia (NMRR-08-965-2120). The authors express deepest gratitude to the Director General of Health, for permission to publish this article.

Date of submission: November 2010
Date of acceptance: August 2011

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European Centre for Nanotoxicology: A Proactive Risk-assessment Nanotechnology Initiative

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Nanotechnology is one of the key technologies of the 21st century and is associated with high expectations. However, the larger surface area of nanoparticles makes them highly reactive compared to the larger sized particles of the same chemistry. Due to their size, they are able to cross differing biological barriers resulting in both, desirable and undesirable effects. Current knowledge about toxicological effects is limited and standardization of nanomaterial application is poor. Thus, a paradigm shift towards more proactive assessment has been identified. There are several international (European Commission, Organization for Economic Co-Operation and Development) and national key institutions active in the field of nanotoxicology. In 2007, the European Centre for Nanotoxicology (EURO-NanoTox), an Austrian hub for scientific knowledge in the field of nanotoxicology, was founded. This Centre acts as a national contact point with international visibility for researchers and industries, and it has co-operative partnerships on academic and industrial levels. The variety of the scientific backgrounds and techniques offered by the partners allows the centre to describe biological actions of nanoparticles from different perspectives and to embed them into international research. Additionally, EURO-NanoTox is in co-operation with the key institutions on the European level to ensure that human health and the environmental safety aspects of nanotechnology are adequately addressed.

Key words: Nanoparticles; academia; Austria; hub; functions; toxicity; national contact point; international visibility; researchers; industries; co-operation; human health; safety aspects

Nanotechnology is, along with biotechnology and information technology, one of the technologies of the 21st Century that have far-reaching implications for science, industrial development and the creation of new products. Therefore, nanotechnology is considered highly important for successful economic development over the coming decades. Nanotechnology is a collective term that relates to different techniques in the nanometer range: the production, study and application of structures. Molecular materials, internal interfaces and surfaces with critical dimensions or production tolerances ranging from a few to about a hundred nanometers are the studied structural factors. In the most important industries, it is increasingly recognized that the control of structural and functional properties of novel materials — so-called 'Advanced Materials' — on the nanometer scale is the key to technological advances and the new products that will conquer emerging markets (Hansen 2009). Besides the use of nanotechnology in material science, the great impact of nanotechnology are expected to alter medicine. Nano-based techniques in the fields of diagnostics (e.g. imaging, biosensors etc.) and therapy (e.g. drug delivery, drug targeting or regenerative medicine) are creating new possibilities in medicine (Baumgartner *et al.* 2003; Yokoyama 2005). Cancer therapy along with the treatment of viral and a number of degenerative diseases has shown significant progress with nano-based techniques (Estella-Hermoso de Mendoza *et al.* 2009; Sokolov *et al.* 2009; Surendiran *et al*. 2009; Thomas *et al*. 2009; Yeo & Xu 2009).

However, despite the obvious benefits of such advanced materials, there can be potential adverse effects on the environment and people due to the fact that humans are exposed to nanoparticles through various routes: inhalation via the respiratory tract, dermal absorption/penetration through hair follicles, ingestion by the gastrointestinal tract and injection. Furthermore, the toxicology of these materials has not been investigated sufficiently. The degradation processes of advanced materials (e.g. waste deposit, air, and groundwater) are still being studied while nanostructered materials are being distributed in the environment. Until now, it has not been possible to show whether nanoparticles that are ingested or inhaled from the environment are systemically absorbed on a larger

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magnitude and if it is possible to calculate their long-term effects (Colvin 2003; Krug 2005).

In addition to the desired physico-chemical changes, a modification of toxicological behaviour has been observed due to the structuring of the materials on the nanometer scale. Systematic studies exist regarding the effects of environmental nanoparticles (ultrafine particles) in relation to a reported increase in the incidence of cardiovascular disease and propensity for asthmatic disease (Oberdörster 2000; Oberdörster *et al*. 2004; Oberdörster *et al*. 2000; Oberdörster *et al*. 2005). The changes of the toxicological potential, which were due to the reduction of the material to the nanometer range, were negated a few years ago. In many cases, the importance has only been recognized in recent years. People and the environment are permanently exposed to nanostructured materials as a result of an ever-widening use and the effects of their release from within their life cycle; these effects are not negligible. Therefore, a profound knowledge of the toxicological potential of nanostructured materials, breakdown products, penetration of and metabolism in the human body and their emission is of enormous importance.

The knowledge of toxicology, the possibility of critical assessment of the potential danger of using standardized testing procedures and the systematic studies carried out on nanomaterials are determined by public acceptance. Public acceptance is a prerequisite for the sustainable and successful development of nanotechnology. A poor acceptance (e.g. caused by a lack of awareness in the field of toxicology) could probably lead to a negative trend in perception similar to that of genetic engineering.

Due to the fact that nanomaterials are increasingly present in our environment, international experts have a growing interest regarding this issue. It is increasingly clear however, that there is a tremendous need for standardization. Characterization of nanostructured materials in (physiological) media is still neglected. Moreover, many of the *in-vivo* studies carried out with mice or rats have used overly high doses of the investigated nanostructured material. This demonstrates that the results are not conclusive and that a classification of the key parameters for assessing the toxicity of nanostructured materials is urgently needed. The aim of this article is to introduce the European Centre for Nanotoxicology (EURO-NanoTox), an Austrian hub for scientific knowledge in the field of nanotoxicology. In the first part, we particularly focus on summarizing international activities related to nano-safety. In the second part, the historical background of the centre's founding as well as the structure (including the partners on academic and industrial levels) is described, followed by an explanation of the intentions behind EURO-NanoTox. Additionally, the core-function of the Centre (i.e. development and implementation of standardized *in-vitro* and *in-vivo* tests for the determination of the toxicity of nanostructered material) which demonstrates the necessary basis is illustrated in more detail.

From International to Austrian Needs in the Field of Nanotoxicology

In the field of toxicology in recent years, a paradigm shift towards a proactive risk assessment has been identified. Public reporting has increased significantly, making the need for the objective communication of risks paramount. Public opinion and acceptance of nanotechnology contribute in four main areas and therefore must be given special consideration: (a) public attitudes; (b) public perception; (c) the role of the media and (d) trust from those who communicate the risk in public behaviour and attitudes (Schuler 2004). These developments are also taken into account on international scientific levels and are recognized by the European Commission. Janez Potocnik, a member of the Commission for Science and Research until November 2009, cited this: '*Nanotechnology is a key area where Europe leads the way and we must ensure that this remains so. The potential of nanotechnology for European industry and society is enormous so we need to research on clear strategy and effective measures in this area. At the same time we must consider eventual health, safety and environmental risks and address them as early as possible*.' (Aktuelles 2005). The bidding of the 7th Framework Program of the European Union reflects this trend by making a specific call for clarifying research in the field of toxicology.

Another initiative in this field sets the Organization for Economic Co-operation and Development (OECD) with the 'Sponsorship Program for the Testing of Manufactured Nanomaterials'. This programme pools expertise and funds the safety testing methods of specific manufactured nanomaterials (MNs). The priority list includes 13 MNs for testing based on materials which are in, or close to, commerce: Fullerenes (C60), single-walled carbon nanotubes (SWCNTs), multi-walled carbon nanotubes (MWCNTs), silver nanoparticles, iron nanoparticles, titanium dioxide, aluminium oxide, cerium oxide, zinc oxide, silicon dioxide, dendrimers, nanoclays and gold nanoparticles (OECD 2010a).

Additionally, the OECD describes the endpoints for which the MNs should be tested (see Table 1 to Table 6) (OECD 2010a).

The programme involves OECD member countries, non-member economies and other stakeholders. An actual overview is demonstrated in Table 7 (OECD 2010b).

In 2004, Donaldson and colleagues claimed, '*We suggest that a discipline of nanotoxicology be built up to address the new potential threats that widespread use of*

Table 1. OECD endpoints: Nanomaterial Information/Identification (OECD 2010a).

Nanomaterial information/identification
Nanomaterial name (from list)
CAS Number
Structural formula/molecular structure
Composition of nanomaterial being tested (including degree of purity, known impurities or additives)
Basic morphology
Description of surface chemistry (e.g. coating or modification)
Major commercial uses
Known catalytic activity
Method of production (e.g. precipitation, gas phase)

Table 2. OECD endpoints: Physical-chemical properties and material characterisation (OECD 2010a).

Physical-chemical properties and material characterization
Agglomeration/aggregation
Water solubility/Dispersability
Crystalline phase
Dustiness
Crystalline size
Representative Electron Microscopy (TEM) picture (s)
Particle size distribution — dry and in relevant media
Specific surface area
Zeta potential (surface charge)
Surface chemistry (where appropriate)
Photocatalytic activity
Pour density
Porosity
Octanol-water partition coefficient, where relevant
Redox potential
Radical formation potential
Other relevant physical-chemical properties and material characterization information (where available)

Table 3. OECD endpoints: Environmental Fate (OECD 2010a).

Environmental fate
Dispersion stability in water
Biotic degradability
Ready biodegradability
Inherent biodegradability
Simulation testing on ultimate degradation in surface water
Soil simulation testing
Sediment simulation testing
Sewage treatment simulation testing
Identification of degradation product(s)
Further testing of degradation product(s) as required
Abiotic degradability and fate
Adsorption-desorption
Adsorption to soil or sediment
Bioaccumulation potential
Other relevant environmental fate information (when available)

Table 4. OECD endpoints: Material Safety (OECD 2010a).

Material Safety
Where available:
Flammability
Explosivity
Incompatibility

new nanoparticles could bring in support of the growth of a safe and sustainable nanotechnology industry' (Donaldson *et al*. 2004). The term 'nanotoxicology' was introduced into literature and Austria became involved with various activities right from the beginning.

Table 5. OECD endpoints: Environmental Toxicology (OECD 2010a).

Environmental Toxicology
Effects on pelagic species (short-term/long-term)
Effects on sediment species (short-term/long-term)
Effects on soil species (short-term/long-term)
Effects on terrestrial species
Effects on micro-organisms
Effects on activated sludge at WWTP
Other relevant information (when available)

Table 6. OECD endpoints: Mammalian Toxicology (OECD 2010a).

Mammalian Toxicology
Pharmacokinetics/Toxicokinetics (ADME)
Acute toxicity
Repeated dose toxicity
If available:
Chronic toxicity
Reproductive toxicity
Developmental toxicity
Genetic toxicity
Experience with human exposure
Other relevant test data

The network NanoNet Styria was the first in Austria to touch upon the topic of nanotechnology and has dealt with nanotoxicology from the beginning. Initiated through these regional activities in nanoresearch, the Austrian Nanoinitiative was founded at the federal level. The group, which has been working within NanoNet Styria with bionanotechnology, evolved into BioNanoNet Forschungsgesellschaft. In 2004, the Austrian Nano-initiative announced the program 'National co-operative Research and Technological Development in Collaborative Projects.' BioNanoNet worked as an administrative co-ordinator for the proposal of the joint project 'Nano-HEALTH — Nano-Structured Materials for Drug Targeting, Release and Imaging' (<www.nano-HEALTH.at>). This project deals with nanostructured materials and integrated the toxicological concerns as a sub-project. International experts have critically evaluated the submitted research project. They have positively reviewed the project twice. The budget for 'Nano-HEALTH' was allotted at 8 million Euros for the time period of 2005 to 2012. The toxicological work under this project was the basis for the establishment of the European Centre for Nanotoxicology.

In 2007, giving active support to decision makers to implement an Austrian strategy on nanotoxicology, Helge Torgersen and Frank Sinner laid down the basis in a joint recommendation to the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) regarding the questions of risk and societal issues in nanotechnology. These recommendations summarized the state-of-the-art nanotechnology, and it's risk assessment as well as the possible effects on human health. Additionally, they outlined the knowledge gaps that needed closing and the methods that would ensure safe and sustainable development of the entire field of nanotechnology. The authors also proposed a set of strategies to implement these recommendations on a short- , medium- and long-term basis. Some aspects of these recommendations were implemented by the funding of the project Nano-Trust managed by the Austrian Academy of Science.

The core function of Nano-Trust is to provide a point of contact for issues dealing with the potential health and the environmental risks of nanotechnology for citizens, the government and politicians. Furthermore, a multi-disciplinary team has established an annotated literature database that covers different aspects of nanotechnologies including the effects on human health, ecotoxicity, and governance. The team consists of the Austrian Academy of Science, Environmental Agency, BioNanoNet Forschungsgesellschaft mbH and the Austrian Agency for Health and Food Ltd (AGES).

European Centre for Nanotoxicology

The key to the development of safer nanomaterial (including the factors mentioned above) is the establishment of inter-disciplinary networks of nanomedicine and the transference of existing knowledge in Austria. In order to focus this necessary expertise in Austria, EURO-NanoTox from the BioNanoNet Forschungsgesellschaft mbH was founded in 2007.

EURO-NanoTox is the Austrian hub for scientific knowledge in the field of human nanotoxicology. The Centre's science and networking industry contributes significantly to improving safety in the workplace when dealing with nanostructured material.

EURO-NanoTox is designed to address all aspects of nanotoxicology and is a national contact point with international visibility for researchers and industries; it is managed by the BioNanoNet Forschungsgesellschaft mbH, a non-profit network company active in the field of pharmaceutical development. The partners of the EURO-NanoTox are Joanneum Research, the Medical University of Graz, the Karl-Franzens-University of Graz, Seibersdorf Laboratories GmbH, BioMed-zet Life Sciences GmbH, the University of Salzburg and

Table 7. Actual table of OECD sponsorship arrangments (August 2010) (OECD 2010b).

Manufactured nanomaterial	Lead sponsor (s)	Co-sponsor (s)	Contributors
Fullerenes (C60)	Japan*, United States*		Denmark, China
Single-walled carbon nanotubes (SWCNTs)	Japan*, United States*		Canada, France, Germany, EC, China, BIAC
Multi-walled carbon nanotubes (MWCNTs)	Japan*, United States*	Korea, BIAC	Canada, France, Germany, EC, China, BIAC
Silver nanoparticles	Korea, United States	Australia, Canada, Germany, Nordic Council of Ministers	France, Netherlands, EC, China, BIAC
Iron nanoparticles	China	BIAC	Canada, United States, Nordic Council of Ministers
Titanium dioxide	France, Germany	Austria, Canada, Korea, Spain, United States*, EC, BIAC	Denmark, Japan*, United Kingdom, China, Germany, Japan*, United States
Aluminum oxide Cerium oxide Zinc oxide	United States*, United Kingdom/BIAC United Kingdom/BIAC	Australia, Netherlands, Spain Australia, United States, BIAC	Denmark, Germany, Japan*, Switzerland, EC, Canada, Denmark, Germany, Japan*, Netherlands, Spain, EC
Silicon dioxide	France, EC	Belgium, Korea, BIAC Spain, United States*	Denmark, Japan* Austria, Korea Denmark, United States, EC
Dendrimers Nanoclays Gold nanoparticles	BIAC South Africa	Korea, United States	EC

* Indicates integrate alternative test methods being performed.
Countries in red indicate that only alternative methods are being performed.

the University of Vienna. The variety of the scientific backgrounds and the techniques offered by the partners allows the Centre to address biological actions of nanoparticles from different perspectives (see standard-method-catalogue on <www.EURO-NanoTox-at>). The EURO-NanoTox is in collaboration with national and international working parties and is an open network that is accessible to all Austrian groups active in or interested in the field of nanotoxicology. Furthermore, EURO-NanoTox establishes strong co-operation between key institutions on a European level. EURO-NanoTox is involved in all major activities in the field and is a data contributor in the OECD Working Party on manufactured nanomaterials (WPMN) on the international level.

The Centre is active in the following areas:

1. The development and structuring of the field of nanotoxicology in Austria
2. The development, establishment and implementation of standardized *in-vitro* and *in-vivo* toxicological evaluation techniques for nanostructered material
3. The development of national and international research projects on nanotoxicology
4. To provide industry with a tool kit of evaluation techniques for the *in-vitro* and *in-vivo* measurement of the toxicological potential of nanostructured material as well as experimental procedures and interpretation of the results
5. The active establishment of international contacts with key players in the area of nanotoxicology
6. The active monitoring of relevant literature and the provision of an information point for interested scientists and industry partners; and
7. Participation in and organization of comparative studies including ring studies.

The core function of the Centre, however, is to develop and implement standardized *in-vitro* and *in-vivo* tests for the determination of the toxicity of nanostructured materials. This is absolutely necessary for the systematic investigation of toxicological effects as well as for toxicological mechanisms. Hence, the EURO-NanoTox

Figure 1. Anticipated co-operation of EURO-NanoTox on a European level.

was conceived as a vehicle that would bring all these aspects together. Through the application of standardized methods in a quality assured environment, expensive failures in product development and/or potential hazards occurring upon product release can be avoided.

The toxicological profile of a given nanostructured material is determined by multiple parameters, including but are not limited to size, payload, composition and geometrical structure. Thus, it is essential to develop, in each case, an individual toxicological strategy tailored to each unique nanostructured material. The strategy should reflect current literature-based knowledge and enable an approach that would be both cost-effective and well structured (Figure 2).

EURO-NanoTox prepares such testing strategies, accompanied by an overview of the relevant published information. The risk assessment and the development of a strategy for the determination of the nanotoxicological profile constitutes the first step in the toxicological testing of each novel nanostructured material.

Additionally, when gaps in the portfolio of available methods become visible, they will be filled by the development of new methods within the context of national or international research projects.

Starting with the formulation of testing strategies for nanostructured materials and with the preparation of a review to evaluate state of the art literature, nanostructured materials are characterized in different (biological) media according to their size, size distribution, surface, agglomeration and zeta-potential. These are the significant factors influencing the standardization of a method. Standardized protocols addressing nanoparticle-specific interferences by the inclusion of additional controls are used for these assays (Figure 3).

The systematic *in-vitro* toxicology is based on cytotoxicology and hemotoxicology concerning the effect of the port of entry into the human body (pulmonary, dermal, nasal, buccal, oral, and endothelial) and the effect onto specific organs (liver, kidneys, spleen). Additionally, a 3D liver model can be used for testing metabolic activity, cell viability, cell toxicity, biochemical assessment of ROS generation (oxidative stress), CYP450 activity (xenobiotic metabolism), stress and genotoxic as well as inflammatory responses. Genotoxic effects are identified by the assessment of changes in the structure of chromosomes and DNA.

Ex-vivo models (e.g. Franz cells, see Figure 4) are used to investigate the permeability/penetration of nanostructured materials across the oral mucosa.

Evaluations of the *in-vivo* effect of nanoparticles include blood count and clinical chemistry (serum parameters for liver damage, kidney function, inflammation, and immune response), histopathology and immunohistochemistry, all of which address specific questions (proliferation, inflammation, oxidative stress etc.).

An improved understanding of tissue specific toxicology of nanoparticles is critically dependent on the development of procedures that will be able to sample the tissue micro-environment in a manner that enables continuous sampling, i.e. without taking biopsies. Open Flow Microperfusion (OFM) enables such an approach to be realized in a highly effective and elegant manner given that it: (i) is a minimal invasive procedure; (ii) allows continuous sampling and (iii) enables the full spectrum of analytes to be harvested from the surrounding milieu, i.e. ranging from small molecules to nanoparticles (micro-dialysis in contrast employs a catheter containing a semi-permeable membrane). The technical scheme of the OFM-technique is illustrated in Figure 5.

The latter features allow a broad spectrum for analysis of all potential nano particles and substances (electrolytes, small molecules, peptides or proteins) to be performed. All these expertises are collected in the 'Assessment of Toxicological Effects by *in-vitro* and *in-vivo* Assays and Open Flow Microperfusion'-folder available on the EURO-NanoTox Homepage (www.EURO-NanoTox.at).

SUMMARY AND OUTLOOK

The pooling of the scientific expertise of all the partners involved and the formation of a link with the structured network of BioNanoNet Forschungsgesellschaft mbH has facilitated the creation of a broad base for a toxicology centre. The embedding of this know-how in international research and development landscape in collaboration with regulatory bodies and authorities has led to the extension of EURO-NanoTox as an international hub. The core functions of the Centre, however, are: (i) to serve as the Austrian junction point where industry and science can submit their nanostructured materials for investigation regarding human toxicity and (ii) to develop and implement standardized *in-vitro* and *in-vivo* methods for the determination of the toxicity of nanostructered materials (including workplace safety). This is absolutely necessary because without this basis of determining toxicity, no systematic investigation of the toxicological effects would be possible. Therefore, EURO-NanoTox was conceived as a vehicle by which the co-ordination of these aspects would

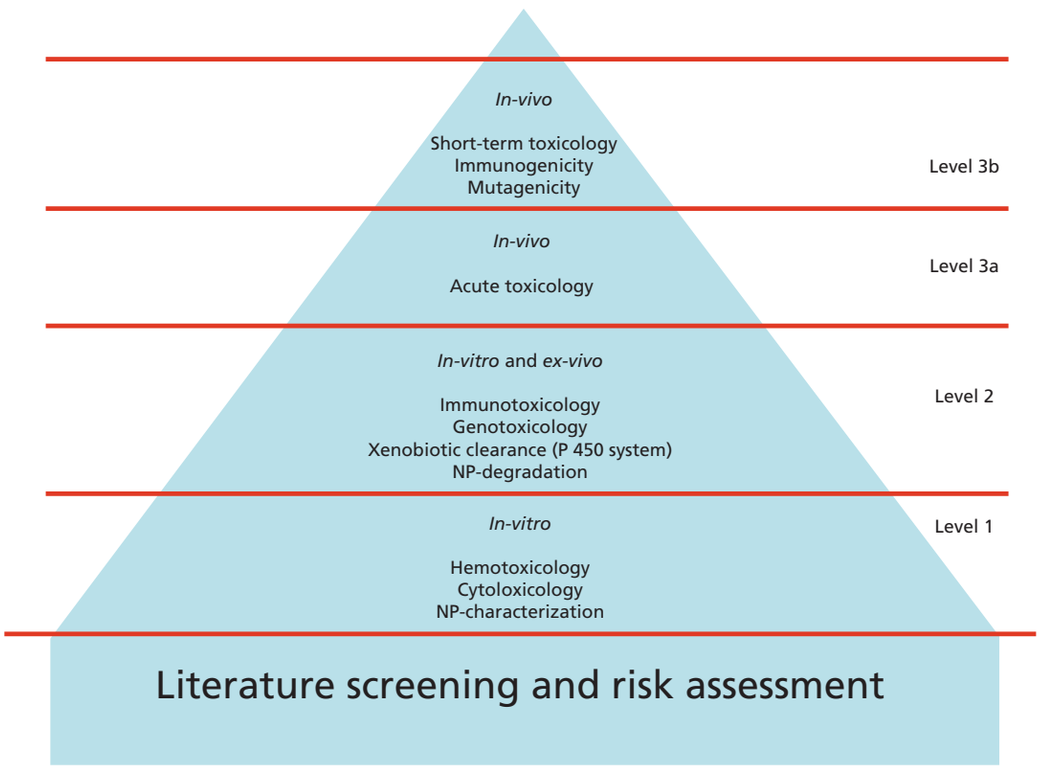

Figure 2. Risk assessment and development of a strategy for the determination of a nanotoxicological profile.

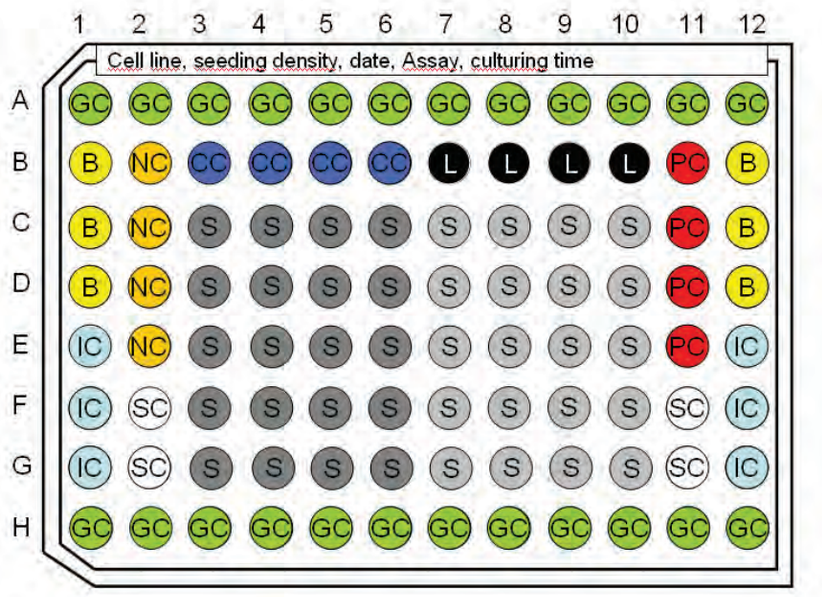

Figure 3. Layout for standard cytotoxicity testing comprising various controls, growth control (GC), blank (B), control with cells and nanoparticles but without assay reagent (CC), lysis (L), solvent control (SC), control with particles and assay reagent (IC), negative particulate control (NC) and positive particulate control (PC), and sample (S) in relevant dilutions.

Figure 4. *Ex-vivo* permeability model: Franz Cell.

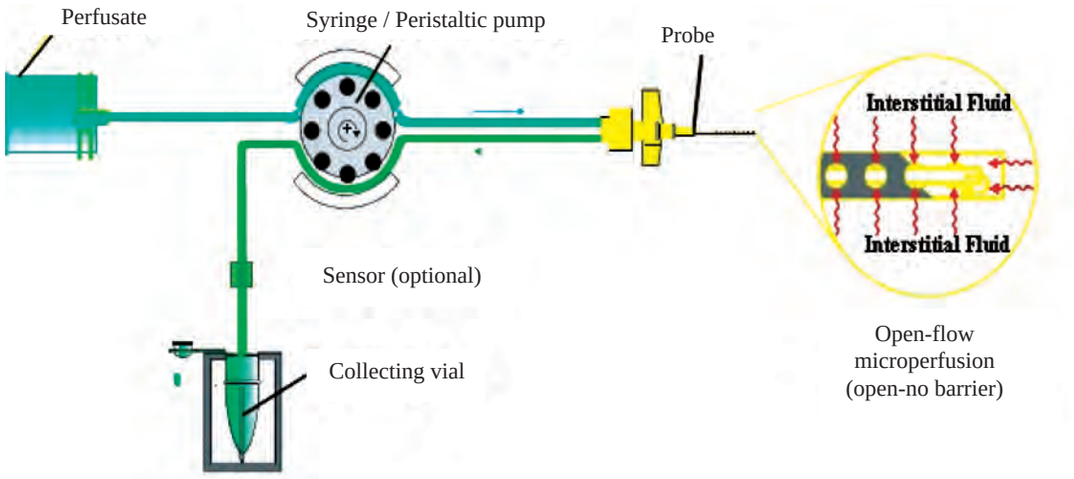

Figure 5. Technical sheme of the OFM-technique.

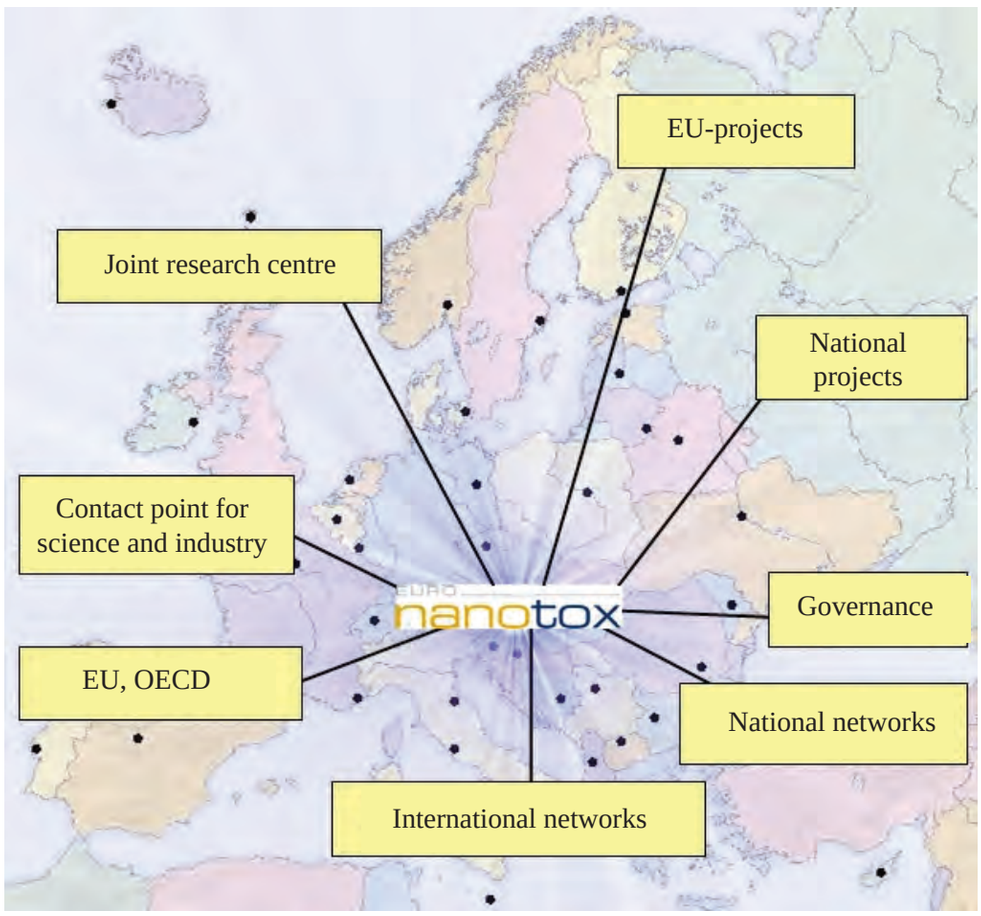

Figure 6. International and national embedding of EURO-NanoTox.

be made possible. Through the application of standardized methods in a quality assured environment, costly failures in product development or potential hazards due to product release could be avoided. Besides the applied aspect of nanotechnologies for scientific expertise, EURO-NanoTox builds in the area of workplace safety. Furthermore, the centre elaborates upon the requirements for a European information platform in order to ensure that the workers and decision makers, who are responsible for the safety of the employees, have access to important emerging knowledge in the field of nanotechnology.

In future, EURO-NanoTox would also serve as a scientific foundation for regulatory aspects, as for example worker safety/workplace safety. EURO-NanoTox would provide valid scientific data and perform validated scientific experiments to address the potential toxic profile of nano-structured materials. Furthermore, EURO-NanoTox was also eager to pursue strategic collaborations with other European nanotoxicology centres which would lead to the establishment of a European nanotoxicology network. This network would help to exchange recent investigations and innovative methods between different European member states and promote the development of European standards to help ensure the successful development of nanotechnologies as a key for European growth (*Figure 6*).

Aspects of converging technologies have the capacity to be viewed in a negative way by the public. The development of scientific expertises, provisions for the availability of information and management for public expectation would be important for the acceptance of this innovative technology.

Date of submission: January 2011
Date of acceptance: March 2011

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Strategic Roles of Industrial Statistics in Modern Industry

M.A. Djauhari[1]

Industrial statistics is an important part of the management system in any industry that strives to continuously improve quality and increase productivity and efficiency. That system covers supply chain management, production design and prototyping, production process and marketing. Industrial statisticians, industrial engineers and industrial leaders should work together hand in hand, in the same language, to ensure that the process and products are as expected. The system itself is never complete. Thus, the usefulness, manageability and reliability of all statistical models used in the system are to be considered as first priority, but those skills are not sufficient. Industrial statisticians should also, of course, be able to come and go between the two poles: statistics and industry. This requirement needs a good understanding about the culture of these poles and how to conduct a mutual symbiosis. One of the principal bridges between these cultures is statistical process control (SPC). This paper is to show that modern industry cannot escape from SPC, especially in a multivariate setting. This setting, which characterizes modern industry, consists of two philosophical problems: how to order data and how to measure process variability. Our recent research results sponsored by the Government of Malaysia will be presented to illustrate the challenging statistical problems in modern industry.

Key words: Industrial capability; process variability; quality system; statistical process control; manufacturing process; productivity; efficiency; multivariate setting

IMD World Competitiveness Yearbook (2009) puts Malaysia at the 18th rank of the most competitive countries of the world. IMD defines 'competitiveness' as: '*How nations and businesses are managing the totality of their competencies to achieve greater prosperity*'. Competitiveness is not just about growth or economic performance but should take into consideration the 'soft factors' of competitiveness, such as the environment, quality of life, technology, knowledge, etc. In that list, USA is still at the first rank followed by Hong Kong and Singapore. USA is indeed a very serious country in industrial competitiveness, innovation, ethics and leadership. These are the core factors of the standard practice to achieve the highest competitiveness in USA. See Malcolm Baldrige National Quality Program (2008) for the details. That manual contains the criteria, the framework and programme for excellent performance. Among the 10 ASEAN countries, only five are in IMD's list and Malaysia is at the second place as the most competitive country right after Singapore (Table 1).

There are only 15 Asian countries in the list. Malaysia is one of the big four with Hong Kong, Singapore and Japan. It is far above the following European countries i.e. France (28th world rank), Portugal (34), Spain (39), Poland (44) and Italy (50) as can be seen in Table 2.

It is no doubt that Malaysian industries including the agro, finance, health care, information, manufacturing, service and the tourism industries which are supported by excellent political will and political stability are the principal contributors to Malaysian world competitiveness. The problem is 'How to maintain and continuously improve the world competitiveness that has already been achieved?' This is a multidimensional problem that needs the strong involvement and commitment of Malaysian people.

This paper attempts to elaborate the responsibility and commitment of university industrial statisticians to safeguard modern Malaysian industry, especially in developing new statistical process control (SPC) tools and procedures in multivariate settings. SPC is chosen as the main topic of this paper since it is the backbone of all manufacturing processes. In the next section we will begin our discussions on the position of industrial statistics in modern industry. Section 3 characterizes what modern industry is about, as viewed from a statistical stand point. In Section 4, we go directly to the recent developments in improving quality, increasing productivity and efficiency (QPE) through reducing process variability. Additional remarks and recommendations on industrial statistics program in university will be presented at the end of this paper.

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Table 1. Five most competitive ASEAN countries.

World Rank	Country
3	Singapore
18	Malaysia
26	Thailand
42	Indonesia
43	Philippines

Table 2. Fifteen most competitive countries in Asia.

World Rank	Country
2	Hong Kong
3	Singapore
17	Japan
18	Malaysia
20	Mainland China
23	Taiwan
24	Israel
26	Thailand
27	Korea
30	India
36	Kazakhstan
41	Jordan
42	Indonesia
43	Philippines
47	Turkey

STATISTICS AND INDUSTRY

There are four principal sectors in industry. Supplies, including natural resources, are at the first sector. The second involves manufacturing while the third deals principally with marketing and after sales services. The fourth sector focuses on technological research, design and development (RDD). All sectors are closely related to statistics, especially statistical modeling which is most extensively used to describe industrial system. Modern industry uses statistical approach for at least two reasons: (i) management cost is low (efficiency is high) while management quality is kept high and (ii) management process is fast (productivity is high).

In the first sector, where supply chain management is part of it, design of experiment (DOE) and statistical significance test (SST) are indispensable tools. In the second sector especially in production process control, it is customary to build a statistical hypothesis of how the production process system could work. In the third sector, marketing research usually dominates all industrial statistics activities. It is qualitative in nature and more explorative than confirmative. In marketing research one of the most challenging problems is how to quantify a qualitative data set based on certain optimality criteria. The last sector, RDD, is what is dealt in this paper. In particular, research in inventing new statistical tools (and or improving the existing tools) and new methodology to continuously improve the quality and increase productivity and efficiency (QPE) of manufacturing process. This will ensure the competitiveness of industry. Due to its important and strategic role in shaping the society, all statistical activities must comply with *Statistics Act 1965* (Laws of Malaysia Act 415) and the Fundamental Principles of Official Statistics in United Nations Statistics Division (1994).

We assume industrial statistics as tools to interpret QPE systems and solve any problems occurring in those systems. It is mathematical in nature. Therefore, when we work with statistical modeling, the principal guidance is what Albert Einstein has mentioned: '*As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality*'. Thus, it is the uncertainty of the model that we have to manage. A more practical guideline is given by G.E.P. Box who said: '*All models are wrong but some are useful*'. Those prophetic words tell us that usefulness, manageability, and reliability of model are the key success factors in industrial statistics.

The history of QPE improvement can be traced back to the era of Confucius (551–479 BC) when the silk industry emerged in the mainland of China and human civilization needed 24 centuries before it became statistical or quantitative. In the early 20th century, William S. Gosset made it statistical when he invented 'student t-statistic' to control the quality of the production process at the brewery of Arthur Guinness & Son. He was a statistician from New College, Oxford. Around two decades later, the statistical approach became a standard practice in industry after the invention of a 'control chart' by Walter Shewhart in 1924 to control and monitor the quality of the production process. This is the year when modern industry began and the era of industrial statistics emerged. Since then, we have witnessed that the number of RDD findings in this area have tended to increase from year to year until present. One decade later after Shewhart's invention, human civilization came up with a control chart for the process in a multivariate setting.

Some experts do not like Shewhart-type control charts because they are slow to react to small shifts in the process. They then developed other types of control chart such as Cusum and EWMA for both univariate and multivariate processes. However, due to the easiness, usefulness and manageability of Shewhart-type charts, these tools are still popular and widely used in world class industry such as AT&T, Airbus, Boeing, General Electric, Toyota, Motorola and many others. See for example, the manual of Boeing Commercial Airplanes, the guideline in General Electric (1997), and the book by Breyfogel III (1999).

Industry needs statistical models and appropriate experience to find suitable solutions to a problem or to

predict how well a design will perform to specifications prior to full scale production. Simulation, destructive and non-destructive tests are usually used in this regard. Testing, statistically or non-statistically, ensures that processes and products will perform as expected. However, a crucial part of the modeling process is the evaluation of whether a given statistical model describes a system accurately. Usually, the easiest way is by checking whether a model fits experimental measurements or other empirical data. The most successful models are those where model evaluation is based on an analytical approach which is mathematical in nature.

We can use Daewoo automotive industry in downtown Seoul as an example to illustrate how important the quality of the process and the product is to stay competitive. In 1995, during a visit there, the author asked the quality assurance (QA) division about the budget allocated for QA activities, RDD is the principal part in that division. The author was informed that the budget was around 25% of total production cost. This was a huge amount of money which was spent by Daewoo in order to stay competitive. They understood that they are in the arena of world intellectual, racing to maintain and improve their competitiveness.

The next discussion will be focused on the second sector. More specifically, on statistical development to have a better understanding about process variability and its applications in process variability monitoring when the process is in multivariate setting. In this setting the quality of the process and products are determined by more than one characteristics and their correlations must be taken into consideration to handle and quantify the complexity of 'quality'. Process monitoring is to ensure that the process stays in control with small variability. We cannot measure and understand the capability of any process in producing good quality products, if the process is not in control.

MODERN INDUSTRY

Modern industry is characterized by the rigorous use of a quantitative approach in all initiatives of QPE improvement. QPE becomes a measurable entity and it should be represented in numbers. Due to the limitation of space, we would focus our discussion on 'quality' for the following reasons. First, quality is the main goal to stay competitive. Second, it is about people as they are in the centre of all activities to reach that goal. Third, quality culture is one of the most challenging things to manage because, as Robert and Sergesketter (1993) point out, quality is a personal matter. The lack of quality culture is the reason why in most organizations, TQM and ISO 9000 certification fail to deliver the required results.

Historically, the term 'quality' was formally defined for the first time in 1940s as 'fit for use'. In this philosophy, customers were not involved in the quality system of any industry. They were outside the system and considered as passive entity. There is no room for them to proactively evaluate the quality. This philosophy was used worldwide until the middle of 1970s.

In 1970s, when quality becomes more and more complex, industries were pushed to put customers in their quality system. Industries had to change their philosophy of quality. Therefore, a new philosophy was born, quality meant 'meet customers' expectation'. This was a totally drastic shift of paradigm. In this philosophy, where customers were put in the system, they became the only judge of quality. However, in late 1990s, industries once again improved their philosophy. Since then, until the present, industries all over the world agree that quality means 'surpass customers' expectation'. This was a quantum leap in modern industry. To stay competitive and survive with excellence, industries realized that 'meet customers' expectation' is not enough. They had to be always creative and innovative, not only to fulfill customers' expectations but to surpass it. An important characteristic of the products of industry under this philosophy was that they provided useful and pleasing unexpected features.

Industrial statisticians need to transform that philosophy into practice using mathematical and statistical tools. Some examples of how to do the transformations is shown by Mason and Young (2009), Djauhari (2010b; 2010c) and Hoerl and Snee (2010). To illustrate this task, in the next section some of our recent research results in monitoring process variability are presented. This area of research was chosen for the following two reasons. First, process variability are the most difficult thing to manage and secondly, 'quality' and 'variability' are always moving in opposite directions; the smaller the variability the higher the quality and the larger the variability the lower the quality. Thus, in industrial practice, to improve 'quality' one has to reduce 'variability'.

MONITORING PROCESS VARIABILITY

There are three scenarios in monitoring process variability. First is the scenario when the number of observations/data (say n) is greater than the number of quality characteristics (say p) i.e. $n > p$. Second, when $n = 1$ and third, when $1 < n < p$. The first scenario is the most common approach in many industries. The second is needed when data collection is expensive or time consuming. The third one is the most recent technology introduced by Mason *et al.* (2009).

In multivariate setting, two important and challenging statistical and industrial problems will always arise: (i) how to order data about the process and (ii) how to measure the variability of the process. The solution of the first problem

is needed to make sure that the process stays in target while the second one is needed when we control, monitor and reduce the process variability. In that setting, the quality of the process is determined by several characteristics whose correlations must be taken into account. This means that all these characteristics must be controlled and monitored simultaneously. It is not correct to control and monitor each of them individually. If we attempt to do so, then the correlation structure is ignored and consequently the decision will be misleading. This warning is still neglected in many industries because of the lack of expertise which needs strong background in advanced mathematics. Here are three examples of products whose quality is in multivariate settings. Due to their confidentiality, the names of the corresponding industries are not revealed.

Example 1. The quality of a flange (electric power isolator, see Figure 1) production process is determined by three characteristics i.e. 'diameter of nozzle', 'thickness of the wall' and 'thickness of the base'. These characteristics, denoted by X_1, X_2 and X_3 in Figure 2, must be controlled and monitored simultaneously because they are correlated with each other.

Example 2. An impeller (see Figure 3) is a vital component of a water pump. The quality of its production process is determined by five characteristics i.e. three diameters (A, B and C), and two thicknesses (D and E) as can be seen in Figure 4. As in Example 1, these characteristics must be controlled and monitored simultaneously because of the correlation between their structures.

Example 3. Figure 5 shows a drive rib IOFLE (Inboard Outboard Fixed Leading Edge) of an aircraft. Its quality is determined by 267 characteristics that must be simultaneously controlled and monitored.

First Scenario

All three scenarios mentioned above have a point in common i.e. process control and monitor are absolutely determined by the way we measure the variability of the process. In the first scenario, generalized variance (GV) is the most popular and widely used measure of variability (Alt & Smith 1988; Woodall & Montgomery 1999; Jaupi 2002; Djauhari 2005; Montgomery 2005). For practical purpose, Djauhari (2009) shows the behaviour (limiting distribution) of sample GV. However, GV possesses some serious limitations as discussed in Alt and Smith (1988), Anderson (2003), Montgomery (2005) and also Mason *et al*. (2009). Due to those limitations, Djauhari (2007) introduces the so-called vector variance (VV) as a new measure. In Djauhari *et al.* (2008) we can see the advantages of VV in manufacturing process variability monitoring.

In Figures 6–8 we present a history of the process variability of flange production, as mentioned in Example 1 and described by Standard GV-chart (Jaupi 2002; Montgomery 2005), Improved GV-Chart proposed in Djauhari (2005) and VV-chart introduced in Djauhari *et al.* (2008), respectively. They describe the actual process variability in different forms. The first chart in Figure 6

Figure 1. Flange for cable of high voltage.

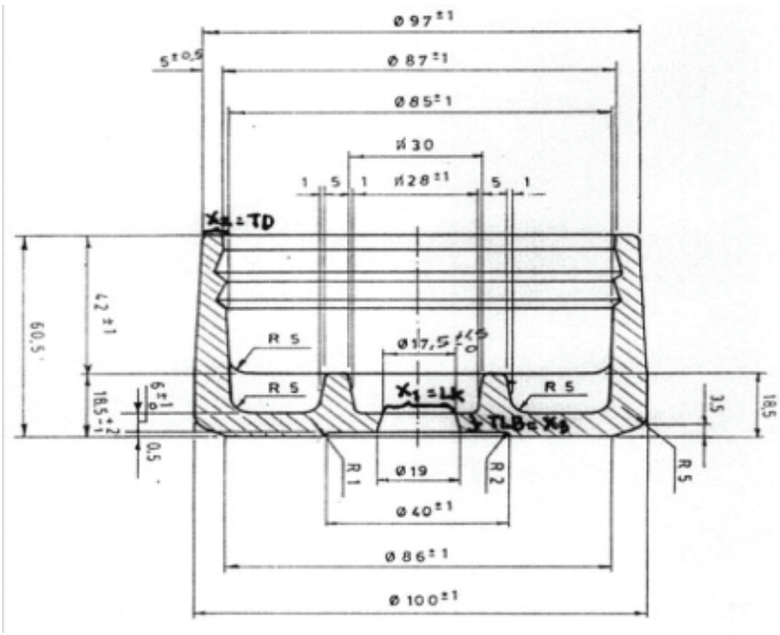

Figure 2. Technical drawing of flange.

Figure 3. Impeller.

indicates that the process is in-control state, all data points are under UCL. The second, in Figure 7 gives an out-of-control signal at the 16th sample (exceeds UCL), while the third (Figure 8), gives two additional signals that were not detected by the previous chart. Figure 7 describes the actual system more accurately than Figure 6 while Figure 7 and Figure 8 are complementary to each other.

An interesting development is presented in Djauhari and Mohamad (2010). Since a single GV-chart or a single VV-chart are not sufficient to describe the process variability, they recommend that these two charts be used simultaneously.

Second Scenario

The use of GV in the second scenario can also be found in Mason *et al*. (2009) in the form of Wilks' statistic. Since that statistic is a scalar multiplication of the ratio of GV issued from a historical data set (HDS) and that issued from the augmented data set (ADS), it possesses similar limitations as GV itself.

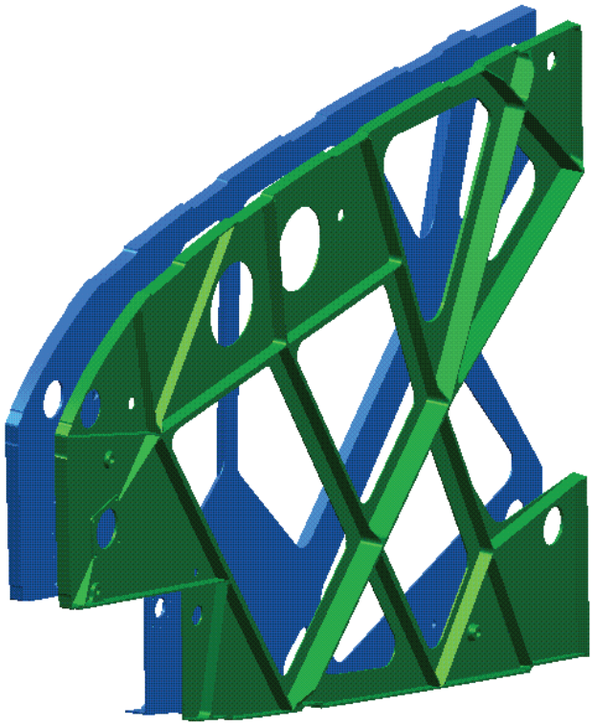

Figure 5. Aircraft wing—Drive rib IOFLE.

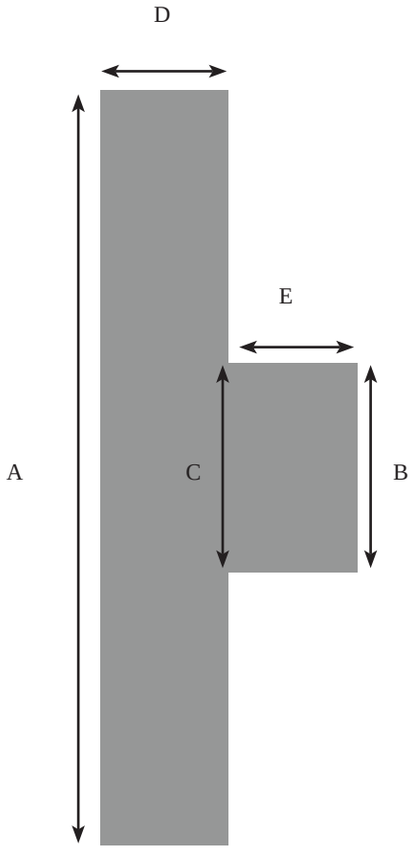

Figure 4. Technical drawing of impeller.

This fact motivated Djauhari (2010a) to introduce a new statistical tool and procedure in SPC. That statistical tool was constructed in the form of the Frobenius norm of the scatter matrix of ADS subtracted by that of HDS. Figures 9 and 10 represent the history of the variability of B-complex vitamin production process with two quality characteristics using the second scenario.

These figures display very different results. They are complementary to each other. This indicates that their simultaneous use is recommended to better understand the production process variability. The monitoring procedure which uses both charts will be more sensitive to the anomaly of process variability compared to the one that uses Wilks chart alone or Frobenius chart alone. This is the new procedure introduced in Djauhari (2010a), where the details of the discussion are shown.

Third Scenario

Third scenario is really new. It was pioneered by Mason *et al.* (2009). They also used Wilks' statistic. Since this statistic has serious limitations as mentioned earlier, an improvement of the monitoring procedure for the third scenario is still open. Our research group at the Department of Mathematics, Faculty of Science, Universiti Teknologi Malaysia, has constructed a new statistical tool that, together with Wilks' statistic, would be able to describe the process

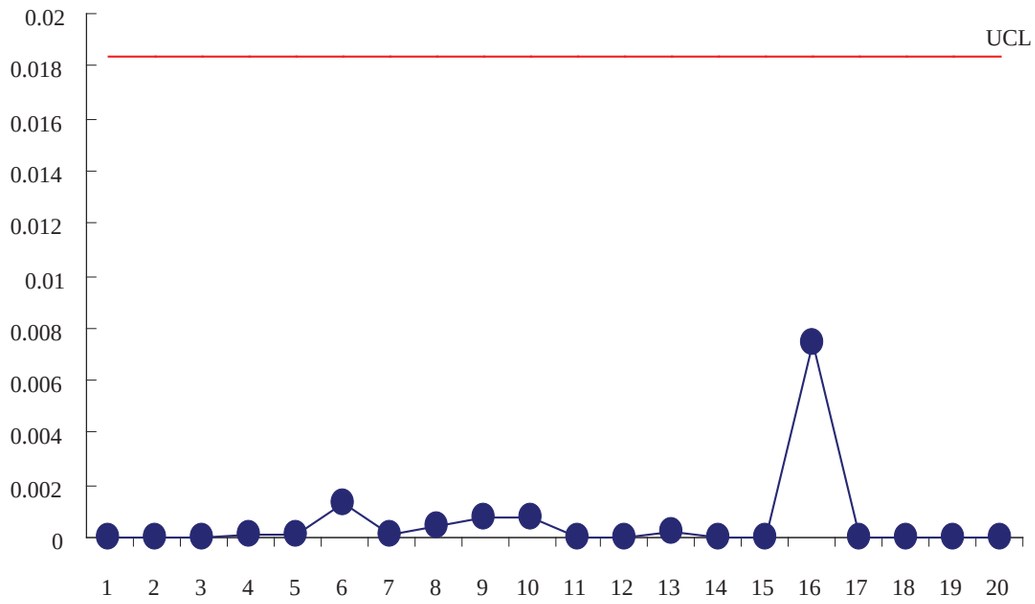

Figure 6. Standard GV-chart.

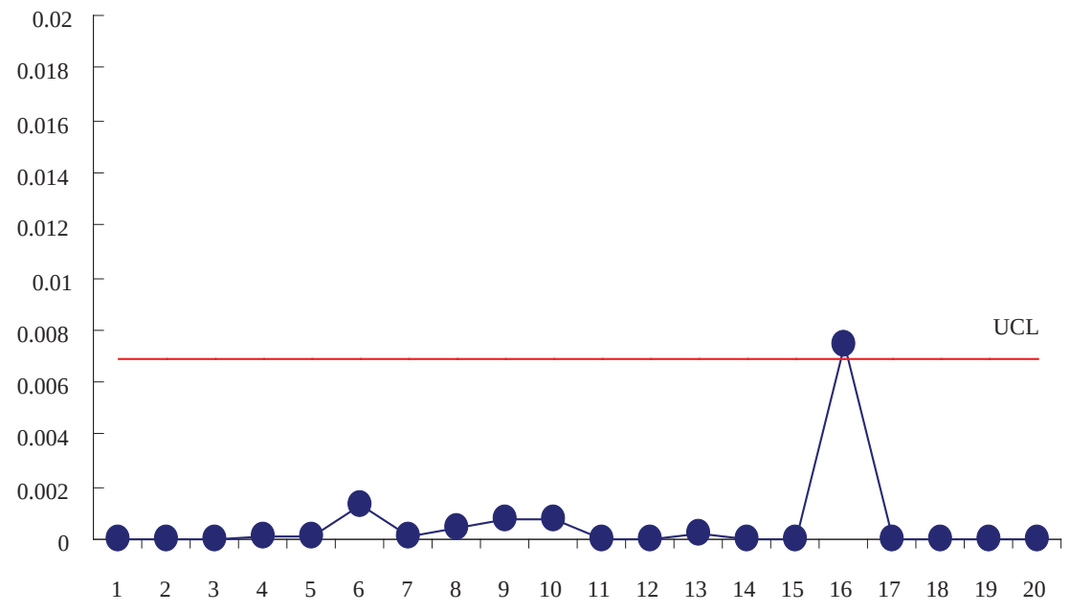

Figure 7. Improved GV-chart.

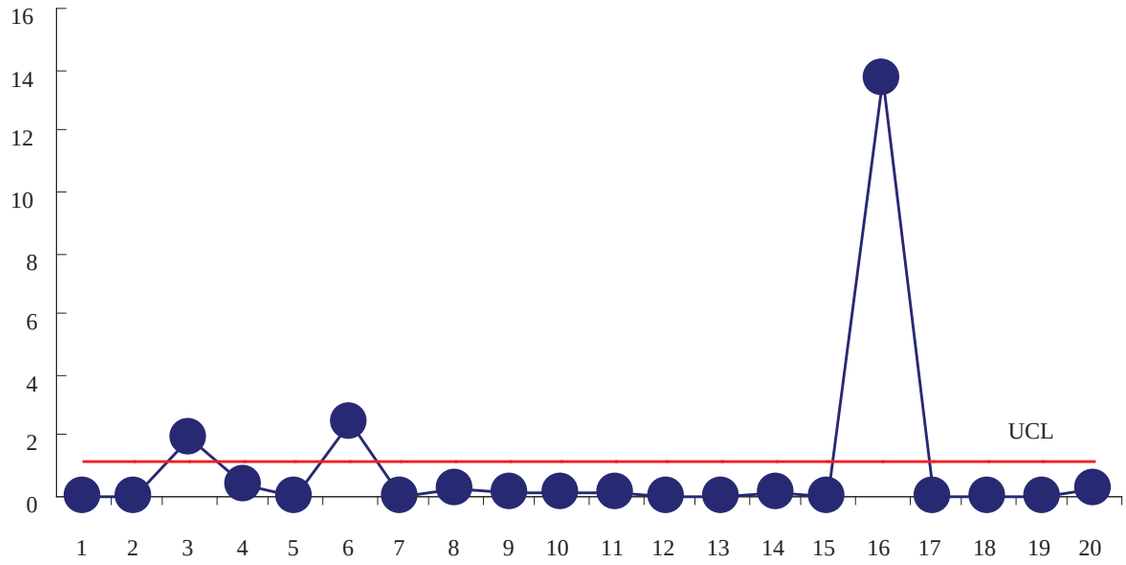

Figure 8. VV-chart.

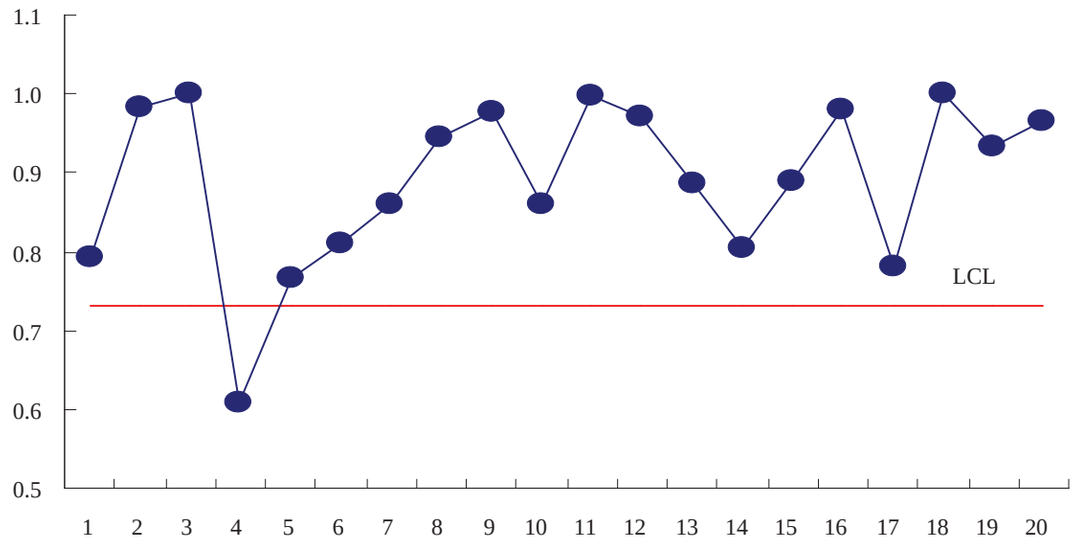

Figure 9. Wilks chart.

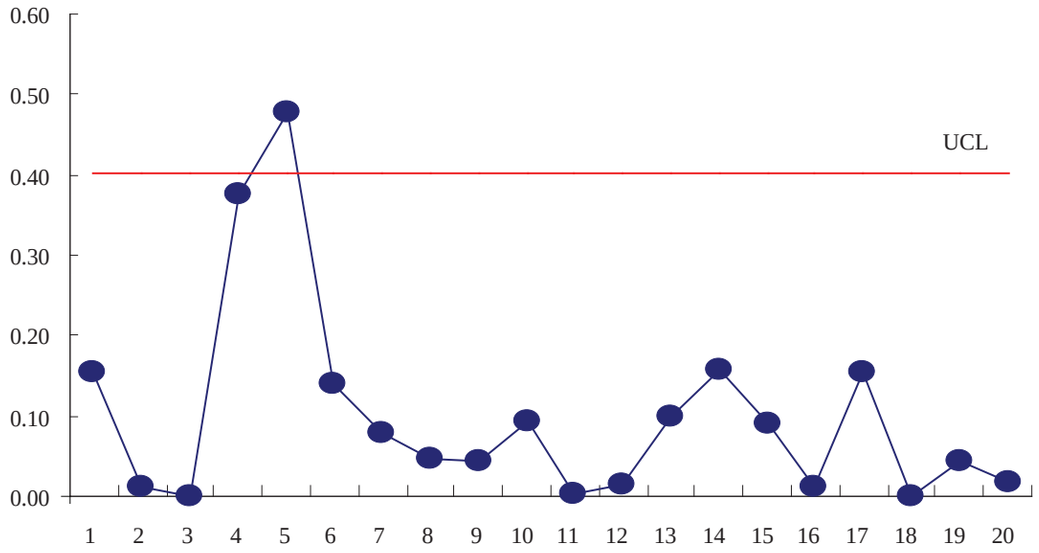

Figure 10. Frobenius chart.

variability better. However, the most crucial problem was to identify the behaviour (limiting distribution) of that tool. This is still in progress and it is not sufficiently complete to be reported here.

The information that has been presented above is to illustrate the importance and strategic role of industrial statisticians in modern industry to invent new statistical tools or to improve the existing ones to be more appropriate to satisfy customers and, increase productivity and efficiency. This is a big challenge for university industrial statisticians to participate in maintaining and improving the world competitiveness of Malaysia through industry.

ADDITIONAL REMARKS

How to develop a procedure that is able to eliminate the error of not signaling an out-of-control state where the process variability has shifted is one of the great problems in the second sector of industry. This is a dynamic research area on how to find a better controlling and monitoring procedure in modern industry. In 1999, Woodall and Montgomery (1999) claimed: '*Research activity in multivariate SPC now seems to be at its highest level*'. Nowadays, one decade later, research in this area is still very dynamic; new important findings have been introduced. For example, Jensen *et al.* (2005) combined a robust estimation method and control charting for Phase I in multivariate setting and Mason *et al.* (2009) introduced a novel method for $1 < n \leq p$.

One more thing needs to be underlined. In the previous sections our discussion is directly related to the second and fourth principal sectors of industry which were more dynamic than the first. In the third sector, where marketing plays a very important role, we witnessed that industry had the power to change the environment, prosperity, society and economy. Therefore, industry has a great responsibility on ethics. Everyone in industry, including industrial statisticians, must consider ethics with great respect. This is the principal reason why in 1994, UNO published the fundamental principles of official statistics. See also Code of Practice in Statistics, Netherland (2004).

RECOMMENDATIONS

The following recommendations for preparing students as future leaders in the field of industrial statistics are enclosed:

- Ethics and quality culture should be placed in the core of the curriculum of industrial statistics programme;
- The curriculum should focus on the fundamentals of industrial statistics that cover all principal sectors of industry;
- An important matter, often neglected in the curriculum, is about laws; *Laws of Malaysia Act 415 (Statistics Act 1965)* as well as laws related to industry such as *Laws of Malaysia Act 156 (Industrial Co-ordination Act 1975)* and *Laws of Malaysia Act 156 (2006)*. These laws should also be put in the curriculum;
- With the advances in computer technology, industrial statisticians can work easily with the very large data sets usually encountered in the biotech industry or the high dimension data sets from the information industry. In such industries, the use of high performance statistical software is a must. However, for SMIs

(small- and medium- industries) or even some big industries the use of open-source statistical software is indispensible. 'Less capital for large benefit' is the *raison d'être* of industry. Therefore, the curriculum should provide students with the opportunity to develop their skill in using open-source as well as high performance software;

- The public knows that there is still a big gap between modern industry needs and academic research work. A lot of academic research works remain published in journals but are not available or applied in the industry. One way to eliminate this condition is to put university laboratories as part of industry research and development centres and, on the other hand, universities puts industry as their laboratory. Hence, the need for industry and academics to work together whereby both parties and the country can benefit from such collaboration;
- Since the curriculum is provided to fulfill the need of students to prepare for their future after the graduation day, it should never be designed as based on the lecturer's expertise. It should be based on the future demands of industry and society at large. This means that the industrial statistics programme should be dominated by hands-on experiences in statistical thinking vis-à-vis industry, statistical engineering and statistical methods and tools. In this regards, industry should be considered as a field laboratory like a hospital in the medical doctor programme; and
- A good curriculum is not enough. The delivery system is as important as the curriculum. Therefore, certain courses must be delivered by university statisticians and others by professional statisticians who have had experiences in industry. Other deliveries would also need collaboration between university industrial statisticians and industrial engineers.

ACKNOWLEDGEMENTS

The author sincerely thank the anonymous referees for their valuable and helpful comments and suggestions. The Government of Malaysia and Universiti Teknologi Malaysia are also sincerely appreciated and acknowledged for the sponsorships under the Fundamental Research Grant Scheme (vote number 78484) and the Foreign Academic Research Grant (vote number 77536), respectively.

Date of submission: December 2010
Date of acceptance: May 2011

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MAHATHIR SCIENCE AWARD FOUNDATION (904190-H)

The Mahathir Science Award Foundation (MSAF) was incorporated on 11 June 2010 to promote scientific research in solving tropical problem, promote international exchange programmes and sharing of knowledge.

The three objectives of the foundation are:

To bestow an award on any scientists, institutions or organizations worldwide in recognition of contributions and innovations towards solving problems in the tropics through science and technology; to confer the award to researches who have made internationally recognized breakthroughs in pioneering tropical research and who have contributed cutting edge tropical research that have brought impact on the well-being of society in the fields of Tropical Medicine, Tropical Agriculture, Tropical Architecture and Engineering and Tropical Natural Resources.

To uplift the stature of the science award to be as one of the prominent international science award, and to oversee the selection process for such a science award.

To encourage excellence in tropical science research that will accord direct benefits to countries in the tropics and the global community; to contribute towards scientific tropical research that will benefit mankind, promote international exchange programmes, sharing of knowledge, and other business development through scientific activities in connection with the foregoing objectives.

The Mahathir Science Award is given to researchers who have made internationally recognized scientific breakthroughs in pioneering tropical research that have brought greater positive impacts on the well-being of society.

As such, this extends beyond the boundaries of Malaysia in order to encourage excellence in tropical science that will accord direct benefits to countries in the tropics and indirectly to the global community. The Inaugural Award was awarded to Professor John Sheppard Mackenzie for his outstanding contribution and breakthroughs in the field of tropical medicine. The first award was presented on 3rd September 2005 by SPB Yang di-Pertuan Agong.

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Tropical Agriculture
Tropical Architecture and Engineering
Tropical Natural Resources

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Recipient of Mahathir Science Award 2011

Prof Yuan LongPing

"His biography, *The Man Who Puts an End to Hunger: Yuan LongPing, Father of Hybrid Rice* (2007) is the only English language publication of a Chinese scientist by the Foreign Language Press of China."

Developing hybrid rice to benefit the people worldwide is one of Prof Yuan's lifelong noble wishes. He concerns not only China's food problems but also the world's hungry. It is he who shares his knowledge, experience, ideas, especially the most valuable breeding materials to other countries for developing hybrid rice. Since 1980, he and his colleagues have trained more than 2000 scientists and technicians from over 30 countries of Asia, Africa and South America on hybrid rice technology. Prof Yuan and his assistants have served for consultancy more than 30 times to develop hybrid rice in many countries such as India, Vietnam, Bangladesh, Myanmar and USA. Currently, hybrid rice has been commercialized in 9 countries including India, Vietnam, Philippines, Bangladesh, Pakistan and USA, etc. These activities have greatly facilitated international hybrid rice development. The total area of rice hybrids was 3.4 million ha outside China in 2009 and the yield advantage is around 2 t/ha generally.

Prof Yuan LongPing, known as 'Father of Hybrid Rice' was born on 7 September 1930 in Beijing. In 1949, Professor Yuan completed his high school courses and entered South-western Agricultural College in Chongqing to major in agronomy. This marked the beginning of his lifelong work in agriculture. Upon his graduation in 1953, he took a teaching job at the Anjiang Agricultural School in Hunan Province. He taught Russian, botany, crop cultivation, breeding and genetics. While teaching, he also conducted scientific experiments involving asexual crossings between crops, using the Russian theories. He however, realised the faults of the Russian models and sought to retool his methodology. By secretly reading Western magazines such as Crop Science, he managed to learn about approaches to science that were different.

The disastrous famine in China from 1958 to 1961 led Professor Yuan to focus his research on the development of high-yielding rice varieties. By then, he had given up his experiments on asexual crossings and began using artificial hybridization to develop new rice varieties. Observing the results of hybridization in corn, he developed the novel idea of utilizing hybrids to increase rice yield.

In the 1960s, utilization of large-scale heterosis was seemed beyond the range of plant scientists for rice, a self-pollinated crop. By the early 1960s, many scientists believed that there was no heterosis for self-pollinated crops like rice and no solutions for high yielding hybrid seed production in self-pollinated crops. However, Professor Yuan took the unknown path into an area full of scepticism and made breakthroughs which made other scientists benefit from this discovery of new knowledge. When news of his work on rice hybrids reached the Western scientific circles, many were sceptical including the International Rice Research Institute (IRRI) in Philippines which had tried rice hybrid research before 1962 but had eventually gave up. However, Prof Yuan introduced Chinese hybrid rice to the world in 1979 at an international conference sponsored by IRRI. The following year, IRRI restored its own hybrid rice research.

When the Great Proletarian Cultural Revolution occurred in China from 1966–1976, intellectuals who dared to voice different opinions were branded as rightists and counter-revolutionaries, and faced being purged from their positions as many were sent to labour in farms in the countryside. Prof Yuan's experimental seedlings were seized because some politicians were outraged when he added 'time' to Mao's eight-word constitution on agriculture. He moved his research work from Hunan to Hainan Island and Yunnan Province. It was on Hainan Island in 1970, that a natural male sterile wild-rice plant (wild rice with flowers containing no pollen) was found. This promising discovery led to rapid progress in the development of

hybrid rice. Consequently in 1972, China's State Science and Technology Commission listed hybrid rice as a key national research project.

Due to his hard work, China's total rice output rose from 5.69 billion tons in 1950 to 19.47 billion tons in 2000. In recent years, hybrid rice has covered an area of 16 million ha, accounting for 57% of the total rice area in China. The increased grains after planting hybrid rice can feed 70 million more people annually in China and provides additional income to thousands of farmer today. This hybrid rice not only gives high percent yield advantages, but also contributes to reduction in the land area of planted rice and the subsequent diversification of crops while still maintaining the quality of the rice.

His techniques for hybrid rice have been commercialised throughout Asia, Africa and the Americas including Vietnam, Philippines, Bangladesh, India, Pakistan, and USA, etc. In 2004, he came to Malaysia and shared his knowledge through lectures on rice hybridization. The Perlis Hybrid Rice Research Centre was established in the state of Perlis with Professor Yuan as the chief consultant. His work has resulted in making rice production more sustainable by increasing the yield productivity well beyond expectations.

Prof Yuan has published over 60 articles and his work has greatly influenced other research fields such as plant sciences, agriculture and applied biotechnology. In recognition of his work, he has received numerous awards and honours, which include the 2000 National Supreme Scientific and Technological award, 2001 Raman Magsaysay Award for Government Service, the 2004 World Food Prize and the 2004 Wolf Prize in agriculture.

The 2011 Mahathir Science Award was awarded to Prof Yuan LongPing in recognition of his courage in independent thinking out of the norm in rice breeding resulting in the innovative development of hybrid rice, a staple food of the tropics that has revolutionized global rice production and sustainability.

As the winner of the Award, Prof LongPing will receive RM100 000, a gold medal and a certificate. The Award will be presented at a Presentation Ceremony, tentatively scheduled in November 2011. As the winner of the Award, Prof Yuan LongPing will be engaged with the Mahathir Science Award Foundation through activities such as lectures, intellectual discourse and networking with researchers.

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Announcements

TRSM TOP RESEARCH SCIENTISTS MALAYSIA

an Academy of Sciences Malaysia initiative

Vision

To build a culture of excellence in scientific research

Mission

To develop a knowledge-hub of top notch Malaysian Research Scientists

The Top Research Scientists Malaysia (TRSM) project and database is an ASM initiative in line with its focus on fostering a culture of excellence in science, technology and innovation (STI).

Malaysian research scientists contribute significantly to the economic growth of the nation via generation and dissemination of knowledge, wealth creation and the productive pursuit of scientific excellence for the benefit of humanity. In relation to this, the TRSM database aims to recognise and showcase the accomplishments of Malaysian research scientists as role models of excellence, mentors to the next generation and leaders to forge ahead with the STI agenda of the nation.

The TRSM database would serve as a resource for the international scientific community, in particular academia, industries and international STI organisations that wish to seek top notch STI expertise in Malaysia. The database would also be a good reference to facilitate nomination of outstanding Malaysian candidates for various national and international STI awards.

Objectives

- To develop a database of leading research scientists
- To recognize and showcase top Malaysian research scientists as drivers of the national science, technology and innovation (STI) agenda
- To identify Malaysian research scientists with pioneer mindset to move the country forward in an innovation-led economy
- To build a critical mass of leading research scientists

Eligibility and Application Procedure

- TRSM application is open to all Malaysian research scientists working in Malaysia whose outstanding achievements in STI have been nationally and internationally recognised
- At the time of application, the applicant should be actively involved in research with at least 10 years cumulative contribution towards the progress of STI
- TRSM application will be opened annually through an online mechanism (the web link for application will be provided in due course)
- The tentative annual closing date for submission of application for evaluation is 31 January

Selection Criteria

The Top Research Scientists Malaysia (TRSM) will be selected through an objective and standardised scoring mechanism based on the following criteria:

(i) Knowledge Generation
(ii) Knowledge Dissemination
(iii) Impact of Research Output

Incentives

Those who are recognised as Top Research Scientists Malaysia can benefit from the following incentives:

- Facilitation by ASM for attachment to world-renowned research labs and centres of excellence by leveraging on ASM's international and national linkages
- International Fund Facilitation Programme (IFFP) to obtain international R&D grants
- Profiled in leading media
- Featured in STI databases as 'Top Research Scientists Malaysia' for promotion and positioning
- Featured in a book on 'Top Research Scientists Malaysia' to be published by ASM

The database is expected to be launched in the 3rd quarter of 2011.

Further updates regarding TRSM will be informed through the ASM website www.akademisains.gov.my

For further information, kindly contact:

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Groundwater Resource Development and Management in Malaysia

The Academy of Sciences Malaysia (ASM) teamed up with the Mineral and Geosciences Department of Malaysia (JMG) on March 2009 and convened a two-day colloquium on groundwater with the theme 'Groundwater Management in Malaysia — Status and Challenges'. Based on the outcome of this national colloquium, ASM and JMG with the support of the Ministry of Science, Technology and Innovation (MOSTI), the Ministry of Natural Resources and Environment (NRE), the Ministry of Energy, Green Technology and Water (KeTTHA) and the National Hydraulics Research Institute of Malaysia (NAHRIM) jointly organised five multi-stakeholder consultative workshops in 2009 with the ultimate aim of developing a Strategic Advisory Report on Groundwater Resource Management. The workshops were structured and organised to address key aspects of groundwater resource management. The topics for these workshops were as follows:

- Workshop 1: Groundwater in the Context of Integrated Water Resource Management—its Management and Governance
- Workshop 2: Research and Development, and Capacity Building Needs in Groundwater Development and Management
- Workshop 3: Making Data and Information on Groundwater Available—constraints and solutions
- Workshop 4: Groundwater Development and Supply for Domestic, Agricultural and Industrial Uses—A Conjunctive Use to Surface Supply; and
- Workshop 5: Promotion and Advocacy of Sustainable Development and Management of Groundwater Resources.

The Workshops were held with participants selected from various stakeholder groups such as relevant government agencies, research institutes, the private sector and non-government organisations, whose linkages to groundwater management related closely with the various issues being discussed. Specialists from academia and relevant agencies were also invited to present position papers on these topics. The position papers, the output of the various workshop groupings and their collective feedback were then collated and published as the ASM Groundwater Workshop Proceedings. This formed the basis of a draft Strategic Advisory Report which was then presented at an open forum comprising of a larger multi-stakeholder audience to obtain multilateral consensus.

This forthcoming finalised Strategic Advisory Report on Groundwater Resource Development and Management in Malaysia will be submitted for consideration and endorsement by the Government of Malaysia.

The Report will include the following:

- Overview of Malaysia's Groundwater Potential and Current Use
- Issues and Suggested Actions
  - Fragmented Policy, Legal and Governance Framework
  - Pollution
  - Lack of Sustained Research and Development
  - Manpower and Human Resources Issues
  - Resource Data Collection, Management and Dissemination
  - Public Awareness and Stakeholder Participation
- The Way Forward
- Strategies
  - Strategy I: Identify and Empower a Lead Ministry/Agency at Federal Level
  - Strategy II: Facilitate States to play a leading role for groundwater management
  - Strategy III: Establish a National Groundwater Research Centre under NRE.
  - Strategy IV: Establish a Standing Committee on Groundwater within the purview of the National Water Resources Council
  - Strategy V: Establish Groundwater Management Committees at State Level
  - Strategy VI: Pass appropriate legislation to strengthen existing legal framework.
  - Strategy VII: Change public perceptions towards groundwater; and
  - Strategy VIII: Development of Detailed Action Plans.

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Making the Third Science Policy Work

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The government's science and technology (S&T) apparatus is now in active consultation to formulate the third national S&T policy (NSTP3) and I have been involved in some of these meetings and have benefitted from them. In an earlier article (New Straits Times, 9 July 2011, p. 18) I had briefly described the two previous policies and given some thought on what the essentials of the NSTP3 should be. I am now offering some further thoughts on the subject.

However, let us first briefly revisit the evolution of science policies in general. Initially it was just a 'science policy' emphasizing the need to do 'good science'. Then it was an 'S&T policy', linking knowledge (science) to its application (technology). Much later there was a move for a policy for "science for technology for development" focusing on harnessing S&T for national development. This gave rise to the concept of science for development (role of S&T in implementing development) and development for science (measures to strengthen S&T capacity). Currently it is "science, technology and innovation (STI)" policy, implying that doing good science is not good enough. Science must translate into innovative technologies at the marketplace. In other words, STI must be an instrument of the economic transformation programme (ETP), (STI for policy) and in turn STI must be strengthened so it can deliver (Policy for STI).

In this connection, it is important to recognize the two crucial parallel systems of research, development and commercialization (R,D&C) and STI. Research gives knowledge (science), development results in technology which becomes innovation when applied or commercialized.

Policy formulation must therefore be inclusive and provide for the total ecosystem. Decoupling innovation from overall STI policy, for example, is simply not innovative. However, once the total ecosystem is recognized and provided for; a number of subsystems such as one for innovation, another for commercialization can be formulated. Therefore, our new policy should be the third National Science, Technology and Innovation policy (NSTIP3).

There are five main components the NSTIP3 must address. **First**, STI for policy: The current national policy is of course, based on the new economic model (NEM) and the ETP with the eight strategic reform initiatives (SRIs), 12 national key economic areas (NKEASs) and 131 entry point projects (EPPs). The recurring key words from the SRIs relate to the weakness or inefficiency of both government and industry in creativity, entrepreneurship, knowledge base, technology, innovation and value addition. These are clear indications of the need for increasing the capacity in STI to support the ETP and take Malaysia out of the middle income trap. Hence, the necessary STI components to support the NKEAs and the EPPs must be identified. In my view, the EPPs at present deal largely with business and financial dimensions. STI components must now be factored in for viability, competitiveness and sustainability of business in the long term. The NSTIP3 must therefore identify the technologies and supporting sciences critical to each of the EPPs and the R&D priorities to meet the needs or to solve existing and anticipated problems. In this respect we can take a leaf from the experience of our rubber and palm oil industries, which remain strong and competitive with the support of their R&D infrastructure.

Second, policy for STI: In order to deliver the support mentioned above, our STI capacity and capability must be strengthened in terms of institutions, mandates, personnel, funding and linkages. Measures to strengthen education and research for capacity building in the sciences relevant to the needs of policy and for public good (e.g. water, energy, biodiversity) must be part of the NSTIP3.

Third, private sector buy-in: There are numerous reports and analyses; the SRIs themselves, highlighting the weakness of our companies in terms of technology and innovation. Since our ETP is to be private-sector driven, getting their involvement and commitment to the STI agenda is crucial. But one cannot expect the SMEs to drive innovation. It is like tasking a 1000cc engine to pull a 40-seater bus. The big companies and especially the GLCs must be the drivers, and the role models. A number of initiatives to secure private sector involvement in the government's STI agenda including cooperative research centres, industry-specific research institutes and research syndication, have already been made as far back as 1997 (Danabalan 1997; Omar 1997). These are, as well as others, should be re-examined by the NSTIP3. The strategy to get private sector buy-in must include presentation (of available innovation), persuasion, incentivisation, legislation, active cooperation and collaboration with government entities. A

designated agency should be assigned the task of engaging and motivating the private sector to become a partner in implementing the STI agenda for the ETP.

Fourth, STI governance: Since STI cuts across many government ministries and must be linked to industries; consultation, coordination, collaboration and harmonization become both important and difficult. Hence, the overall governance for STI must be enhanced. Existing STI institutions and agencies must be reviewed in terms of their legitimacy, authority and capacity including linkages. The return of the Science Advisor and MIGHT to the Prime Minister is a laudable move. Autonomy should be reinstated to Academy of Sciences Malaysia so that it can provide unbiased and timely advice to the government. Parliament should be a platform for debate on STI issues affecting the government, industry and the public. A parliamentary committee on STI could be established. It is assuring that the government is now considering legislation to strengthen STI governance.

Fifth, STI and the community: A supportive and science-literate community is part of the total STI ecosystem. The NSTIP3 must deal with issues of science literacy and enculturization. The "science for all" programme is school, must be re-introduced. It must also deal with an education system that promotes creativity, innovativeness and entrepreneurship. Additionally, the NSTIP3 must deal with ethical issues as well as issues of public interest (safety, health, security and the environment). In view of the above, I am recommending 15 policy responses for our NSTIP3 (see Appendix).

These 15 policy responses under the five major components described above would then provide the foundation for the total national capacity (TNC) in STI that is essential to achieve the national ETP. The TNC comprises: a government committed to providing a comprehensive STI physical and soft infrastructure; a scientific fraternity able to contribute and draw from the global pool of scientific knowledge and technological know-how; a private sector capable of creating wealth through the application of technology and innovation in all sectors of the economy and a society which is science literate, imbued with a culture of creativity, innovativeness and entrepreneurship.

The work of the policy planners is cut out for them. This time round our policy must be supported by the political will to achieve full implementation.

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Appendix 1. Proposal for policy responses.

1) Increasing knowledge intensity in traditional economic sector.
2) Increasing productivity, innovative capacity and competitiveness in manufacturing and targeted economic sectors.
3) Intensifying the capacity for knowledge generation and acquisition.
4) Education and human capital development.
5) Intensifying knowledge content in governance.
6) Enhancement of entrepreneur development.
7) Innovative financing mechanism and support system for commercialization of technology and innovation.
8) Creating a national culture of creativity and innovation.
9) Enhancing knowledge management.
10) Promoting science ethics and smart partnership ethos and practices.
11) Securing private sector buy-in.
12) Enhancing the STI advisory system.
13) Enhancing knowledge in topics of public interest (safety, health, security and environment).
14) Enhancing STI governance.
15) Enacting necessary legislation.

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Global Warming: Can We Do Something?

Ghazally Ismail
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Human activity has 'very likely' been the primary cause of global warming since the start of the Industrial Revolution (18th–19th century). As a new player in industrial transformation, Malaysia can choose to ignore the warnings of global warming. blame. This may not augur well. Release of greenhouse gases have been categorically linked to climate change and global warming. In her march towards industrialization, Malaysia too has contributed to the release of greenhouse gases. Apart from those arising from natural sources, the industrial sector in Malaysia also releases other types of gases such as the fluorocarbons. This is evident from the worsening air quality in some of our cities.

Is the build-up of greenhouse gases unavoidable? Do we have options to improve the situation? We know of knee jerk reactions by some industrialized countries to improve urban air quality by controlling emission from fossil fuel combustion, industrial processes and waste disposal. Until today, the Malaysian Environmental Quality Act has shown little promise in guaranteeing that every citizen can breathe air of a quality sufficiently safe for health and welfare. When it was passed a few years ago, the Act was aimed to set national ambient air quality standards as regards the most commonly found pollutants around us. These standards must not only must be achieved everywhere in Malaysia by specified dates but also must be maintained through programme limiting the emission of existing and new sources of pollutants.

The practicality of dealing with existing and future air quality problems is manifold. First and foremost, we must have a policy that focuses primarily on preventing the generation of air pollutants. The use of air pollution technology to reduce residual emissions will be the next. We should also begin to look hard at the habits of our society that result in air pollution. Managing these habits to minimize pollution is the key and these include a fresh outlook at the movement of people and goods, the location of residences, work and recreation, the production and use of energy and other activities that use fossil-based energy.

Tangible steps need to be put in place. The first approach is to create incentives for energy efficiency and conservation. Increased energy efficiency and conservation are cost effective measures. In the long run, it will result in substantial improvements in air quality and will promote sustainable economic growth. A second step would be to begin restructuring the means by which people and goods are transported. Programme to encourage car-pooling and the use of mass transportation as well as the location of residences closer to work and recreation will have important air quality benefits. A third step would be to look at an alternative process, material or fuel for activity that generates air pollution. A fourth step is the application of best available air pollution control technologies to reduce emissions from major sources. Combustion modifications, particulate control devices and scrubbers could minimize the emissions of air pollutants to our atmosphere. Unfortunately, so far, we have no inexpensive and effective technology available to do so, or any programme for reducing fossil fuel use.

As we plan future actions, we should all subscribe to a philosophy of protecting and keeping the air that we breathe to remain as clean as possible from the impact of human activities. Clean air is essential in supporting a healthy ecosystem for a high quality of life and, ultimately, our own survival. This philosophy involves changing our lifestyles to reduce the generation of pollutants and the consumption of natural resources. It involves a moral position on our part that the air should be clean for both the present and future generations.

As for those in higher places in whose hands we trust to provide us policies and strategies to clean our air, may we remind them that there have been too many signposts of imminent risk and doom for us to ignore. The annual plights of haze blanketing our cities in recent decades have been frequent and too predictable. Open burning, continued emission of toxic fumes and the generation of other air pollutants through our own over-consumptive behavior and activities have been left largely unchecked. The scourge from our own greed and over-consumption has clearly indicated that indeed we have over stepped the line on the question of natural resource exploitation. Maybe the time is also ripe for us to begin thinking of other essentials of life like water and our biodiversity. Here again the signposts are pointing distinctly at the dangers that lie ahead.

The red flag is already up and it is time for us to reflect and take stock of our own polluting and wasteful lifestyles. We can no longer plead our innocence or ignorance. Optimistically, we trust in some radical way, something will be done; the sooner the better. It is not the need of additional

and new institutional legislation, but for more effective enforcement of the existing Acts and Laws. In this respect, we are not asking the government to shift the spotlight from economic development to environmental and resource conservation but to strike a balance between them. On one hand, Malaysian scientists need to examine and bring into correct perspective the forces of both environmental and economic choices that can drive us towards a truly progressive nation. Politicians and industrialists, on the other hand, must be open and sensitive as to cast away any suspicion that hangs over anyone who tries to bring into the public eye any violation of our environmental ethics and norms. Future generations will applaud our foresight and action but will condemn our lack thereof.

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Carbon Cess on Fuel Consumption

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BACKGROUND

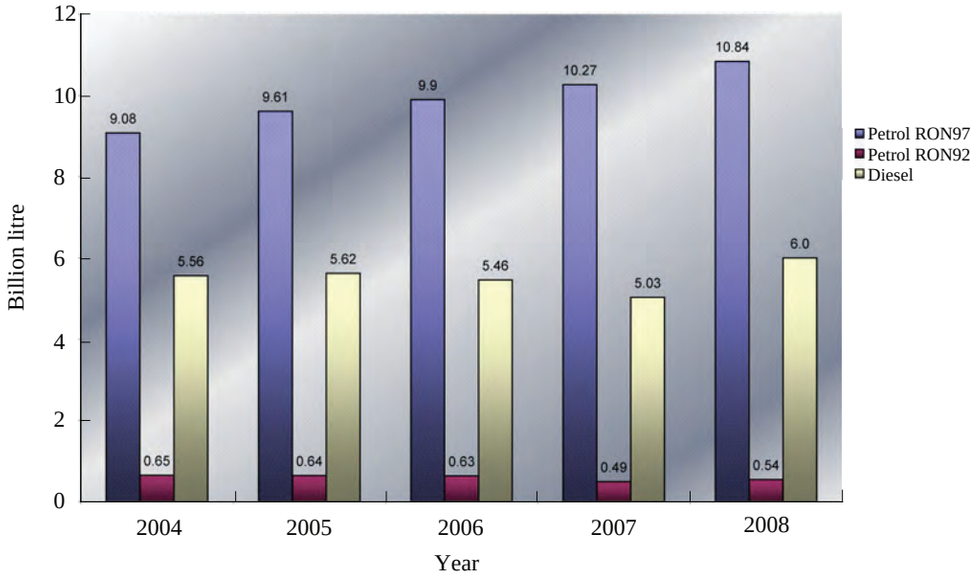
In December 2009, at the UN Climate Change Conference COP 15 in Copenhagen, the Prime Minister of Malaysia, the Rt. Hon. Mohd Najib Abdul Razak, had announced that "Malaysia is adopting an indicator of a voluntary reduction of up to 40% in terms of emissions intensity of GDP by the year 2020 compared to 2005 levels. This indicator is conditional on receiving the transfer of technology and finance of adequate and effective levels from Annex 1 partners, that correspond to what is required in order to achieve this indicator". Malaysia also needs to decouple its GDP from its current relatively high carbon-based energy demand. In trying to meet both these targets, we need to intensify our research efforts in energy-based areas. As government funding in R&D is limited as the aim is for research to be private-sector driven, and with the grim global economic scenario today, it is most unlikely that Malaysia will get any assistance financially or technologically from Annex 1 nations. It is therefore proposed that Malaysia considers implementing a dedicated carbon cess on petroleum products to fund R&D in the country.

This is not a new initiative globally as a number of countries have implemented, or are planning to implement, taxes based on CO_2 emissions, among them being the USA, countries in the EU, and newly industrialized countries from around the world.

Further, the collection of cess is not something new in this country as the production of palm oil, rubber, timber and tin had cess imposed on the commodity, basically based on weight. The cess thus collected was used in driving R&D activities (from fundamental to applied research) in the commodity concerned. Specific legally-sanctioned bodies were set up through regulations promulgated by Parliament to manage the cess, which in many instances, runs into hundreds of millions of ringgit.

MECHANISM OF CESS COLLECTION

Revenue can be collected for the exclusive purpose of funding R&D&C on clean energy activities in the country by dedicating a carbon cess on the amount of fuel (RON 95, RON 97 and other fuel types) consumed by Malaysians [or foreigners (RON 97)] or industries (bunker fuel, jet fuel etc.) yearly (Figure 1). The cess can be managed by the National Science Research Council. This cess will be derived from the existing price of fuel.



Source: Ministry of Domestic Trade, Cooperatives and Consumerism Malaysia (<www.kpdnkk.gov.my>).

Figure 1. Sales of petrol and diesel at petrol pump station from the year 2004 to 2008

Table 1a. Malaysian fuel consumption (RON 95 fuel).

Year	RON 95 (Billion litres)	Carbon cess/litre (RM)	Potential revenue (RM Million)
2008	10. 84	0.05	542.0
	10. 84	0.04	433.6
	10. 84	0.03	325.2
	10. 84	0.02	216.8
	10. 84	0.01	108.4

Table 1b. Malaysian and foreigner's fuel consumption (RON 97 fuel).

Year	RON 97 (Billion litres)	Carbon cess/litre (RM)	Potential revenue (RM Million)
2008	540	0.05	27.0
	540	0.04	21.6
	540	0.03	16.2
	540	0.02	10.8
	540	0.01	5.4

For example, today, the RON95 price is RM1.90/l. If just RM0.05 is taken as carbon cess, it will provide an R&D&C revenue amounting to RM542 million (using the 2008 consumption figures — Table 1a). Conversely, if we consider only RM0.01/l, the carbon cess revenue will amount to RM108.4 million. Various cess scenarios are tabulated. The more fuel Malaysians 'burn up' annually, the more R&D&C funds are generated.

If we were to compute cess collected on the consumption of RON97, the low usage of this fuel will result in low revenues (Table 1b) for R&D&C (ranging from RM5.4 million to RM27 million).

Bunker fuel and other fuel types, such as aviation fuel, have not been considered in this scenario, but suffice to say that if we consider all carbon-based fuel types sold/utilised (including coal) in this country, the cess that potentially can be collected would undoubtedly be immense.

If the cess on carbon is spread to the other fuels mentioned above, this will increase the carbon cess 'spread' to include the aviation industry, transportation (sea and land) industry and energy industry.

Objectives of the Carbon Cess

(i) To fund R&D&C in developing energy efficient appliances and devices;
(ii) To fund R&D&C in developing efficient and economic energy storage batteries;
(iii) To fund R&D&C in new clean energy sources; and
(iv) To fund R&D activities on how to decarbonise our industries (steel, cement, manufacturing etc.).

Later, post-2020 (after the 40% reduction in carbon intensity target from the 2005 level is achieved), the use of these R&D funds could be expanded to fund R&D in other sectors such as the water, health, agriculture and biodiversity sectors.

CONCLUSION

Before the cess can be imposed, the Government should ensure that a series of awareness programme is initiated to have 'buy-in' by the populace. That they are contributing directly to the R&D&C cess, which would be used for funding energy-related R&D&C activities, and hence to them playing their part in CO_2 reduction, are important considerations that the Government need to consider in the programme.

The cess can be managed by the National Science Research Council (NSRC) with the necessary regulations promulgated by Parliament. It is hoped that this proposal will be considered as a 'painless' way to contributing to the nation's coffers to fund R&D&C.

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Green Technology and Innovative Changes

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Awareness and sensitivity on the subject of green technology are currently commanding the attention of the world in the light of rising energy costs and the threat of global warming. Many countries are now recognizing the benefits of researching into and using green technology to reduce their carbon and water footprints and to minimize waste.

There have been many expectations that this field would bring about innovative changes in the daily life of Malaysians. We wish to recommend that the goals in this rapidly growing field of green technology should include:

- Sustainability — that is meeting the needs of society in ways that could continue indefinitely into the future without damaging or depleting natural resources. In short, meeting present needs without compromising the ability of future generations to meet their own needs.

- Innovation — developing alternatives to 'old' technologies that emphasise the usage of fossil fuels or chemical fertilizers for agriculture that have been shown to damage health and the environment.

- Waste reduction — reducing waste and pollution by changing the present patterns of production and consumption, ending the 'cradle-to-grave' cycle of manufactured products towards the creation of products that can be allways reclaimed, re-used or re-cycled, essentially adopting a 'cradle-to-cradle' approach.

- Viability — creating centres of economic activity around technologies and products that benefit the environment, speeding their implementation and creating new career opportunities that are involved in protecting the Malaysian environment.

It is hoped that academia, research institutions, related government organisations, relevant energy stakeholders, etc. would look into aggressively developing relevant R&D initiatives into these areas towards fulfilling our PM's pledge at COP15—United Nations Climate Change Conference, Copenhagen in 2009, to reduce carbon emission levels.

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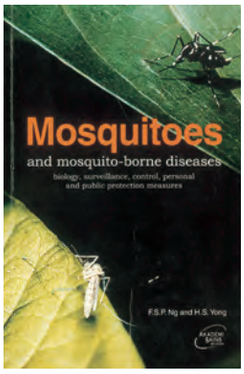

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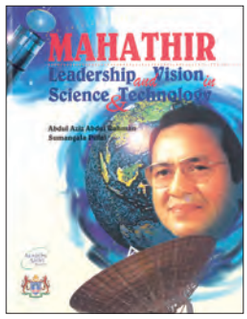

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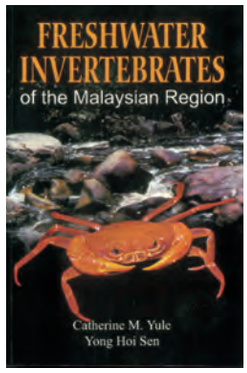

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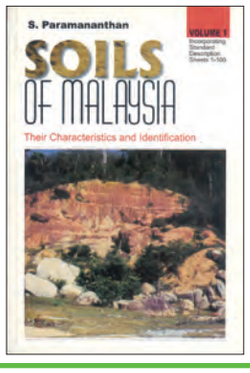

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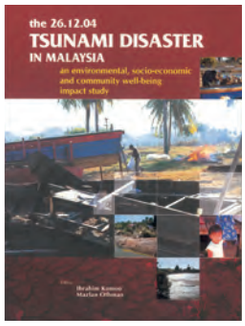

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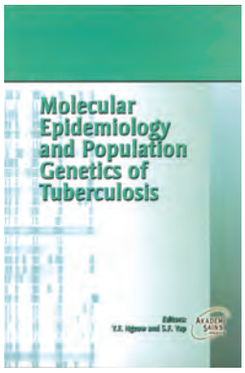

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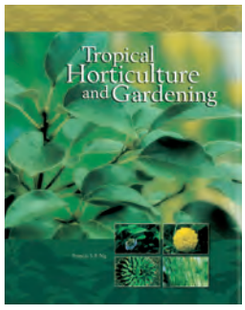

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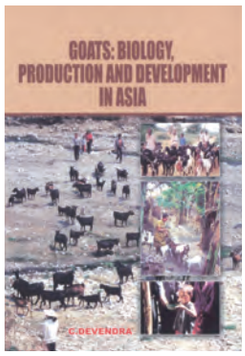

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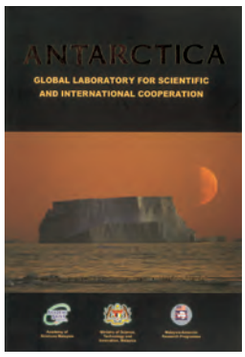

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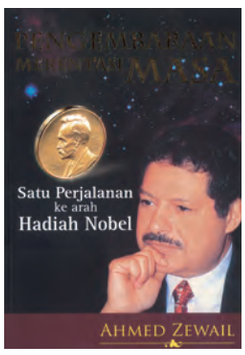

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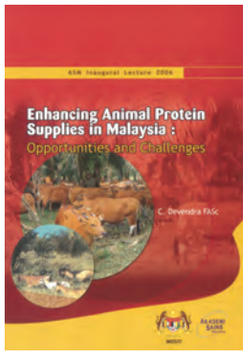

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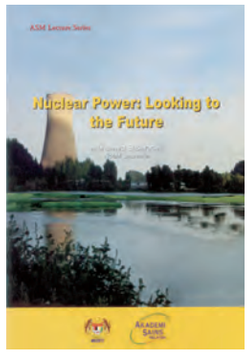

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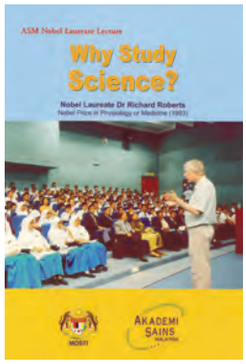

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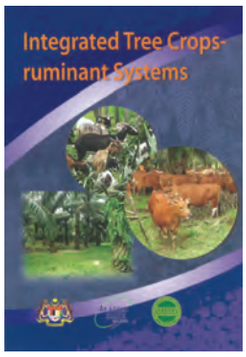

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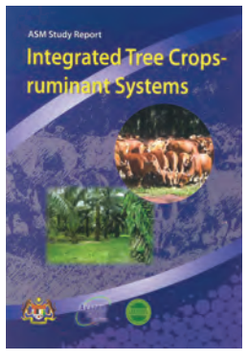

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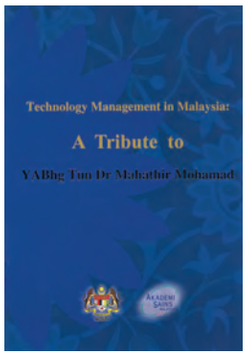

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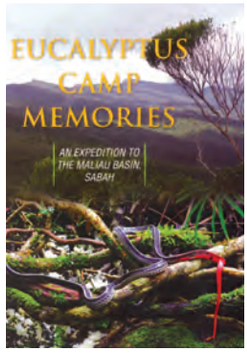

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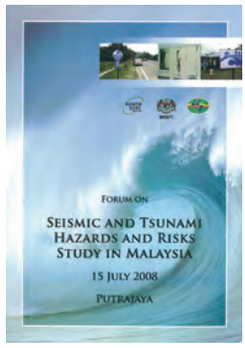

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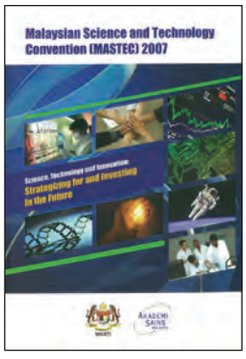

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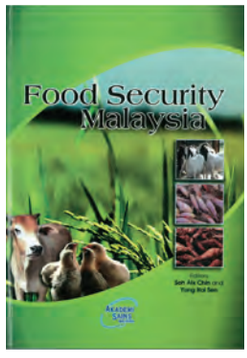

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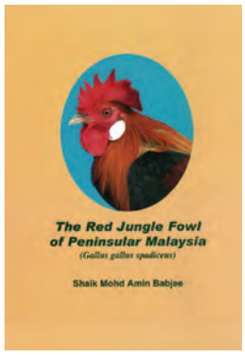

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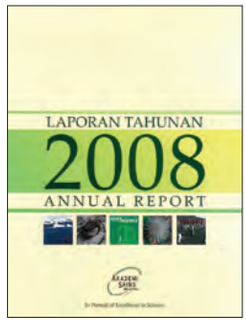

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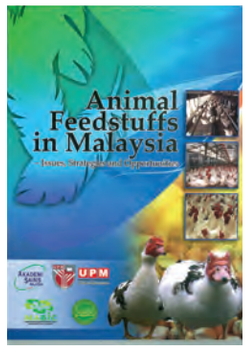

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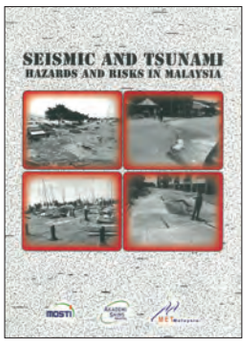

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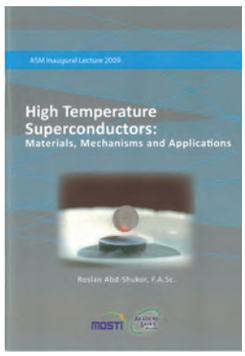

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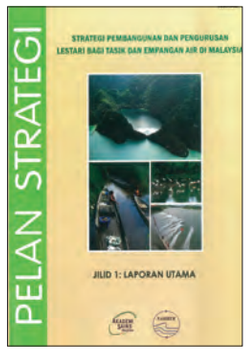

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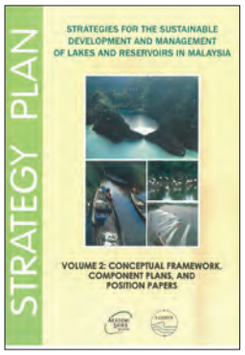

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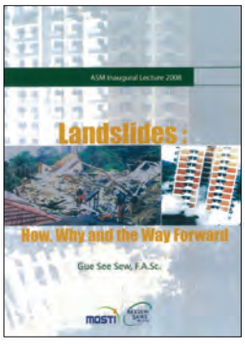

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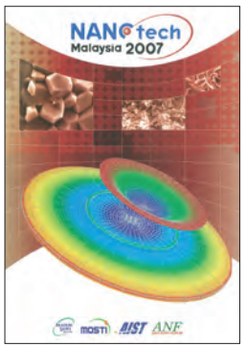

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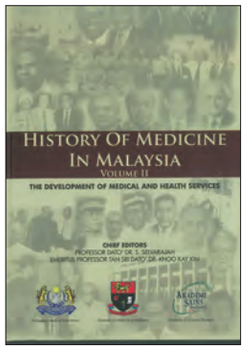

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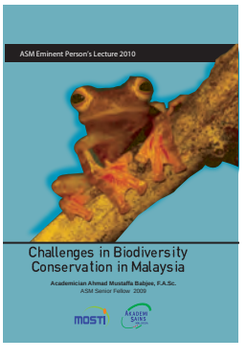

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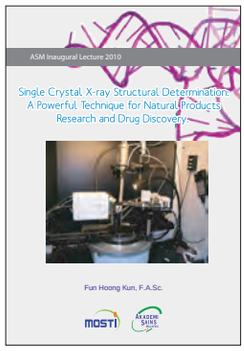

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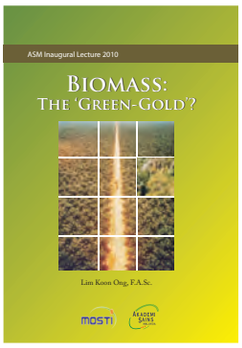

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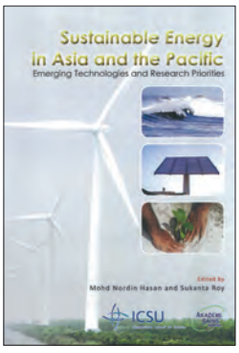

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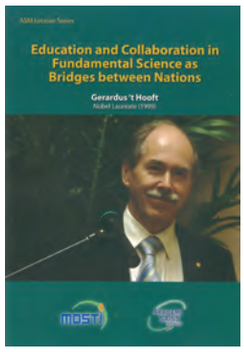

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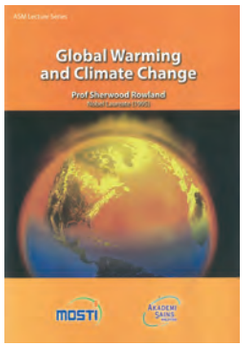

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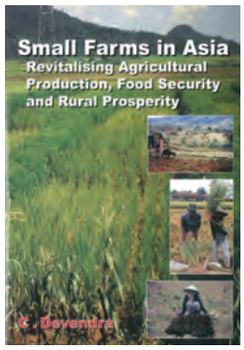

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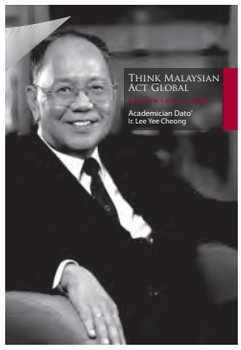

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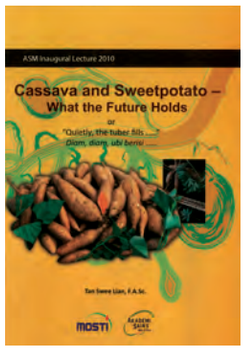

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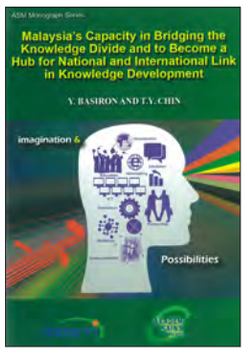

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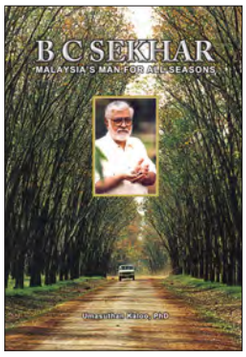

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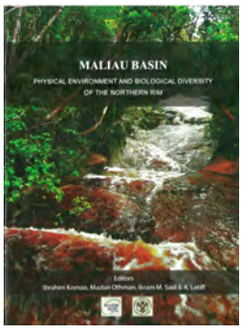

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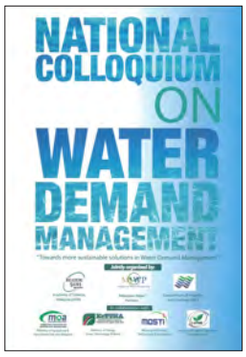

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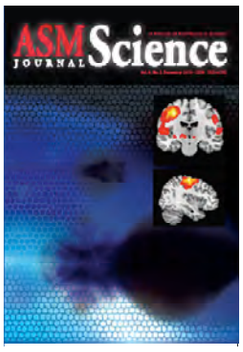

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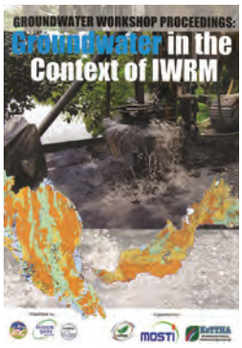

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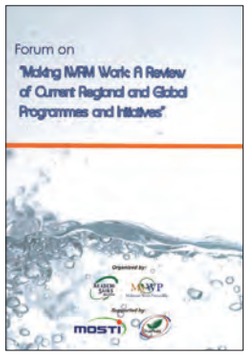

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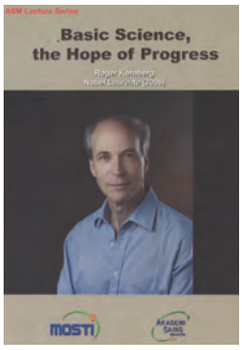

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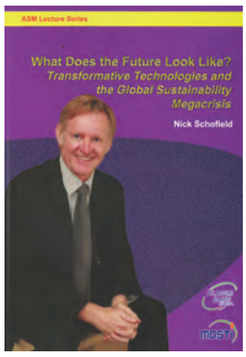

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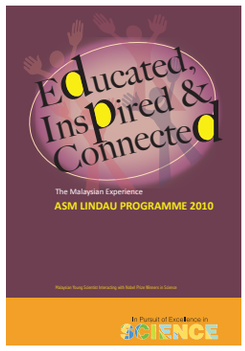

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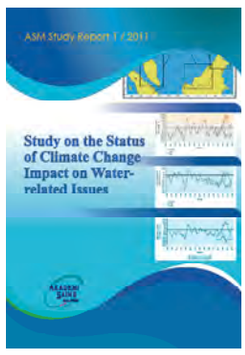

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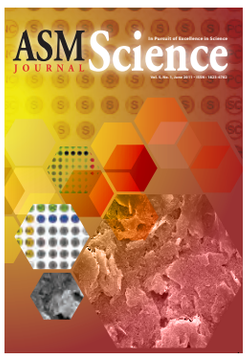

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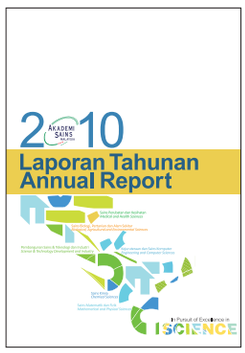

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Monograph

Hyem, T & Kvale, O (eds) 1977, *Physical, chemical and biological changes in food caused by thermal processing*, 2nd edn, Applied Science Publishers, London, UK.

Chapter in a monograph

Biale, JB 1975, 'Synthetic and degradative processes in fruit ripening', eds NF Hard & DK Salunkhe, in *Post-harvest biology and handling of fruits and vegetables*, AVI, Westport, CT, pp. 5–18.

Conference proceedings

Common, M 2001, 'The role of economics in natural heritage decision making', in *Heritage economics: challenges for heritage conservation and sustainable development in the 21st century: Proceedings of the International Society for Ecological Economics Conference, Canberra, 4th July 2000*, Australian Heritage Commission, Canberra.

Website reference

Thomas, S 1997, *Guide to personal efficiency*, Adelaide University, viewed 6 January 2004, <http://library.adelaide.edu.au/~sthomas/papers/perseff.html>.

Report

McColloch, LP, Cook, HT & Wright, WR 1968, *Market diseases of tomatoes, peppers and egg-plants*, Agriculture Handbook no. 28, United States Department of Agriculture, Washington, DC.

Thesis

Cairns, RB 1965, 'Infrared spectroscopic studies of solid oxygen', PhD thesis, University of California, Berkeley, CA.

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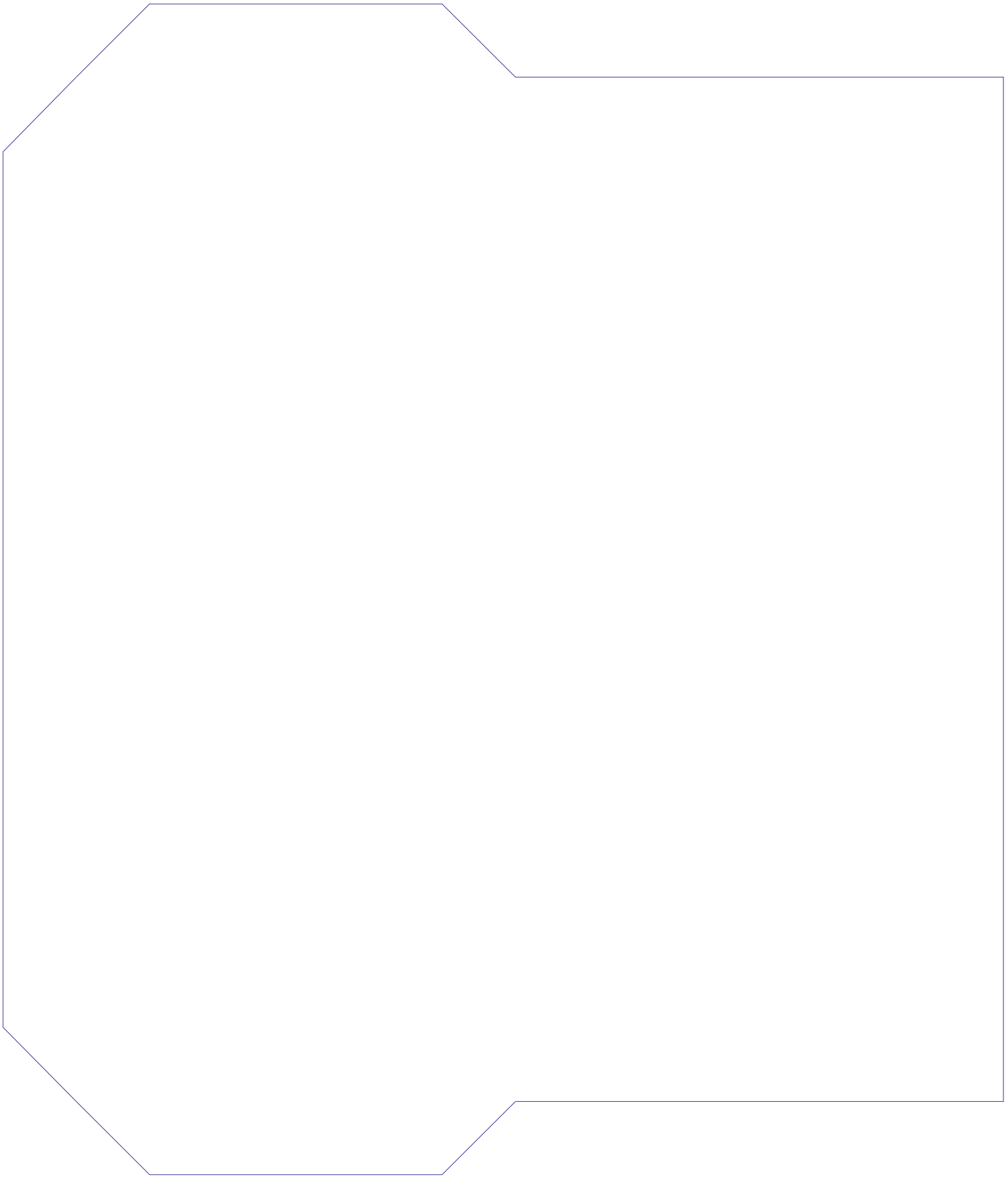

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